National Radiological
Protection Board
Health and Safety
Executive
Consultative
Document

Draft guidance notes for the protection of persons exposed to ionising radiations in research and teaching

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Preface

These guidance notes replace those published by the Health and Safety Executive in 1976. That text had earlier been published as a code of practice by the Department of Employment. The original code was prepared between 1959 and 1963 by an advisory panel for the Radioactive Substances Advisory Committee and was revised in 1968 (further amendments being made in 1972).

Following recent recommendations of the International Commission on Radiological Protection including ICRP Publication 26, and the issue of the European Communities Directive of 15 July 1980 on basic safety standards in connection with ionising radiation, the Ionising Radiations Regulations 198- have been made and the Health and Safety Commission has issued an associated approved code of practice. It has been agreed with the Health and Safety Executive that the National Radiological Protection Board, who assumed the functions of the Radioactive Substances Advisory Committee under the Radiological Protection Act 1970, should prepare new guidance notes for the protection of persons exposed to ionising radiations in research and teaching to reflect all these recommendations and requirements. The following guidance notes, prepared with the aid of an advisory group, take account of all these developments and are published jointly by the Board and the Health and Safety Executive.

[These guidance notes have been prepared by NRPB. Although HSE staff were on the Advisory Group, HSE has not yet fully studied the text and may wish to make certain changes.]

Research and Teaching Advisory Group

WT Baker, BSc, CChem, MRIC, FRSH
PF Beaver, BSc, MInstP, FINucE *(Health and Safety Executive)*
BW Delf, BSc, PhD
JA Dennis, ARCS, BSc, PhD, FInstP *(HSE)*
RE Ellis, BSc, PhD (deceased)
HD Evans, BSc, PhD
DA Gray, ARCS, BSc
J McKie, BSc, FInstP
AS McLean, CBE, MB, ChB, DIH, FRCP, FFOM (deceased) *(National Radiological Protection Board)*
S Rae, MB, ChB, FRCP, FFCM *(NRPB)*
JCA Raison, MD, MB, BChir, MFCM *(NRPB)*
Professor ES Williams, BSc, PhD, MD, MB, BS, FRCP
TO Young, BSc *(HSE)*

Secretary
MJ Butler, MA *(NRPB)*

Note
In these guidance notes

'must'	indicates a legal requirement; a reference to the source is given.
'it is essential that'	is used to describe a practice to be regarded as essential in good radiological practice.
'should'	refers to requirements of the approved code of practice, when a source is given. Without a reference, it indicates a desirable procedure.

For further explanation see 'Introduction'

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Introduction

These guidance notes have been prepared for those who use ionising radiation in a wide range of research work and teaching, such as that under the control of universities, polytechnics, Government Departments or research organisations and for those who work in industrial research laboratories. Ancillary activities, such as the testing and calibration of equipment and the storage and disposal of radioactive materials, are also covered by these notes so far as they are carried out on the same premises. The guidance notes indicate procedures for the protection of all persons who may be exposed as a result of these practices, that is to say all employed persons, apprentices and students, and members of the public.

The scope of these guidance notes does not, however extend to:

(a) medical and dental research involving human subjects (separate medical and dental guidance notes are referred to below);

(b) low-level work with approved radioactive sources and X-ray sets in schools, establishments of further education and colleges of education under the systems of approval of the Department of Education and Science, the Welsh Office, the Scottish Education Department and the Department of Education for Northern Ireland;

(c) training and apprenticeship where radiation sources are used in industry and commerce, and production trials.
[It is intended to refer to guidance notes on the use of ionising radiations in general industry issued by the Health and Safety Executive.]

Users of ionising radiations in research and teaching must comply with the Ionising Radiations Regulations 198-, and the Radioactive Substances Act 1960. They are also required to follow the Approved Code of Practice on Ionising Radiations issued by the Health and Safety Commission, unless it can be shown that a legislative requirement has been met in some other equally effective way. These guidance notes have been harmonised with the guidance notes for the protection of persons against ionising radiations arising from medical and dental use published by the National Radiological Protection Board, and those using ionising radiations which touch on those subjects should consult that publication.(123)

These guidance notes give advice as to how the requirements of the approved code can be met. They also cover many other matters concerning protection against ionising radiation and are intended to form a comprehensive guide to the subject for workers in research and teaching. The requirements of the regulations and approved code, as well as other relevant legislation and important publications, are quoted, summarised or referred to. However, the guidance notes should not be considered as giving an exact legal interpretation of these documents; senior managers, radiation protection advisers, administrators and those concerned, for instance, with the ordering of equipment will sometimes need to consult the original texts. Absence of a reference should not be taken as meaning that there is no legislative or approved code requirement.

The word 'must' is used in these guidance notes where there is a legal requirement, and a reference to the source is given. In the previous code this word was used to indicate an essential requirement in the sense of good radiological practice. This type of requirement is now identified by the words 'it is essential that'. The word 'should' is used in referring to the approved code of practice, in which case the relevant reference is made. It is also, as in the previous code, used to indicate a desirable requirement. The two senses can be easily distinguished. These forms of use are summarised in the note on page iv.

It is realised that some of the recommendations may need to be adapted to local circumstances. It is recommended that departure from an 'essential' recommendation, or 'should' when stemming from the approved code, should be permitted only when specifically authorised by the controlling authority. It is highly desirable that the decision should be made only on the advice of a radiation safety committee or radiation protection adviser and that it should be recorded.

The guidance notes cannot be so detailed as to deal adequately with every set of circumstances that may arise, and it may well be necessary for certain users to obtain more specialist advice. Information may be obtained from the National Radiological Protection Board, the Health and Safety Executive and the Radiochemical Inspectorate.

1 The limitation of radiation dose

1.1 General principles

1.1.1 The International Commission on Radiological Protection (ICRP) has laid down the following basic principles: (58)

(a) No practice shall be adopted unless its introduction produces a positive net benefit.

(b) All exposures shall be kept as low as reasonably achievable, economic and social factors being taken into account.

(c) The dose equivalent to individuals shall not exceed the limits recommended for the appropriate circumstances by the Commission.

1.1.2 To comply with the first principle, the controlling authority* should ensure that radioactive substances, or machines which generate ionising radiation, are utilised in research and teaching only where there is adequate justification for the particular practice. New practices should be the subject of analysis before introduction into a research or teaching establishment, taking account of any national recommendations.

1.1.3 The second principle underlies the guidance given in the other chapters of these guidance notes. It calls for continual re-appraisal of the lowest exposure necessary to achieve the intended benefit from it. The Ionising Radiations Regulations reflect this principle; the 'responsible person' must 'take all reasonably practicable steps to restrict the extent to which all persons are exposed to ionising radiation' (Reg 7(1)). In addition to the initial measures, all procedures should be kept under regular review, and equipment frequently re-examined to ensure that this requirement is being complied with. There should be a continuing appraisal of the doses being received, or likely to be received, to help in ensuring that they are as low as reasonably practicable (ACl/23). Workers must not expose themselves or others to ionising radiation to a greater extent than is reasonably necessary for the purposes of their work (Reg 7(2)).

1.1.4 Requirements on dose limits in Reg 8 give effect to the third principle. Dose limits apply both to persons at work or under training and to members of the public. A dose† in excess of the dose limits would not necessarily have biological significance.

1.1.5 The ICRP distinguishes between two kinds of application of radiation sources in teaching:

(a) the general teaching of science subjects

(b) specialised teaching of subjects concerned with radiations and their uses.

The first type of application is likely to involve a very large number of people and the ICRP recommends additional limitation of dose in order to ensure an acceptably low average dose to the population. The use of ionising radiation in general teaching, both in schools and colleges, should follow Administrative Memorandum 2/76 and appendices and the associated Notes for Guidance. (110, 111) *‡ These guidance notes (for research and teaching) apply to the second type of application which involves a much smaller number of people and is analogous to occupational exposure.

1.2 Dose limits for workers and students

1.2.1 The dose limits for occupationally exposed workers aged 18 years or over are given in Table 1.1. They apply also to adults who are being trained for employment involving occupational exposure or who are obliged to use radiation sources during their studies. For those between the ages of 16 and 18 who fulfil these conditions,§ the annual limits are 3/10‡ of those in the table; for all other persons the annual limits are 1/10|| of those in the table.

1.2.2 The dose limits apply to the sum of the dose equivalent received from external sources during working hours and the committed dose equivalent (see Appendix 1) due to internal sources taken into the body in the course of work. ¶The total does not include exposure to natural background radiation or any medical exposure which occupationally exposed persons may receive as patients or as volunteers in a medical trial approved by an

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*See Appendix 7.

†'Dose equivalent' (see Appendix 1) is frequently abbreviated in these guidance notes to 'dose'.

‡In Scotland, Circular No. 689 (112); in Northern Ireland, un;numbered circular (113)

§These conditions are not made in Schedule 1 of the Regulations.

||Whether or not these particular fractions should apply to the dose limit for the lens of the eye is under discussion by HSE and NRPB — see note to Table 1.1].

¶Unless otherwise indicated, work should be understood to include training throughout these guidance notes.

ethics committee. Annual limits are for a calendar year; the quarterly limit is for any period of three months (Schedule 1).

1.2.3 The effective dose referred to in Table 1.1. is given by the expression $\Sigma_T W_T H_T$ where W_T is a weighting factor recommended by ICRP (58) for each organ or tissue (T) given in Table 1.2 and H_T is the annual dose equivalent or annual committed dose equivalent in that organ or tissue. The five other organs to be considered are those receiving the highest dose equivalents, not including the hands and forearms, the feet and ankles, the skin and the lens of the eye. The exposure of all other organs or tissue can be neglected. When the gastro-intestinal tract is irradiated, the stomach, small intestine, upper large intestine and lower large intestine are treated as four separate organs.

Table 1.1 Dose limits for occupationally exposed workers aged 18 years or over

	Annual limit	*Other limit**
Whole body	50 mSv (5 rem)	
Effective dose (from partial body exposure)	50 mSv (5 rem)	
Abdomen of woman of reproductive capacity		13 mSv (1.3 rem) in a quarter
Abdomen/fetus* of pregnant woman		10 mSv (1 rem) between declaration of pregnancy and delivery§
Lens of the eye	*	
Skin (averaged over any area of 100 cm^2)†	500 mSv (50 rem)	
Hands, forearms, feet and ankles	500 mSv (50 rem)	
Any other organ or tissue (average in organ)	500 mSv (50 rem)‡	

[*Certain differences between Schedule 1 of the Regulations (schedule of dose limits) and the requirements of the Council of the European Communities Directive (82) are under discussion by HSE and NRPB:

	Regulations	*Directive*
Pregnant women	Dose limit for abdomen	Dose limit for foetus
Dose limit for lens of the eye:		
Workers	150 mSv (15 rem)	300 mSv (30 rem)
Trainees (16-18 years)	50 mSv (5 rem)	90 mSv (9 rem)
Members of the public	30 mSv (3 rem)	30 mSv (3 rem)
Other (than annual) limits	Apply to external radiation only (see para 6 of Appendix A to the HSC Consultative Document Nov. 1982)	Apply also to internal radiation

]

†100 cm^2 applies to doses from radioactive contamination; a smaller averaging area should be used for radiation beams (see 7.2.4).
‡See 1.2.4
§See 1.2.8

Table 1.2

Organ or tissue	W_T
Gonads	0.25
Breast	0.15
Red bone marrow	0.12
Lung	0.12
Thyroid	0.03
Bone surfaces	0.03
Each of 5 others	0.06

1.2.4 It should be noted that the dose limit in Table 1.1 for ‘any other organ or tissue’ is subject also to the limit on effective dose. For the gonads, breast, red bone marrow and lung, the limitation on effective dose will result in limits for these organs lower than 500 mSv; if any of these organs could be irradiated without any dose to other parts of the body the annual limit would be $\frac{50}{W_T}$ mSv.

1.2.5 For exposure to external radiation the detailed distribution of dose in the body will not normally be known, in which case the dose limit for the whole body applies to the 'deep dose equivalent' and the dose limit to the skin to the 'shallow dose equivalent' (see Appendix 1). These quantities may be taken to be the quantities measured by personal dosemeters. They are approximately equal to the 'deep dose equivalent index' and the 'shallow dose equivalent index' use of which are advocated by ICRP.(58)

1.2.6 For internal exposure of the body, resulting from the intake of radionuclides by inhalation or ingestion, by absorption through the skin, or by entry through wounds, it is difficult to apply the dose limits directly. It is more convenient to employ annual limits on intake (ALI) which have been derived by ICRP for all the radionuclides of interest(61) (see Appendix 1). When exposure results from inhalation or ingestion, compliance with these limits will ensure that doses to adult workers do not exceed any of the annual dose limits.

1.2.7 When exposure to both external and internal radiation occur together the annual dose limits will not be exceeded if:

(a) $\frac{H_d}{H_{E,L}} + \Sigma \frac{I_j}{I_{j,L}} \leqslant 1$

where H_d is the deep dose equivalent for external radiation received during the year,
$H_{E,L}$ is the annual limit of effective dose equivalent,
I_j is the intake during the year of the radionuclide j
and $I_{j,L}$ is the annual limit on intake for the radionuclide j.

(b) The shallow dose equivalent does not exceed the skin dose limit.

1.2.8 The special dose limit which applies to a pregnant woman (see Table 1.1) can apply only if pregnancy is declared. The woman is not obliged to disclose her pregnancy but is nevertheless advised to do so in order that any necessary additional measures may be taken to safeguard her unborn child (see 2.5.4).

1.3 Exposure in excess of the dose limits

1.3.1 Planned special exposures, which are liable to lead to doses exceeding the dose limits, may be needed in exceptional circumstances when alternative techniques which do not involve such exposures cannot be used. Though such situations might arise very occasionally during research there should never be a need for a planned special exposure during training. Only classified persons (see 2.5) who have volunteered and who are not women of reproductive capacity may be subjected to a planned special exposure and prior authorisation by HSE* is required (see 2.2.10) (Reg 10).

1.3.2 A person who is thought to have received a dose exceeding any of the dose limits must not, during the remainder of the current period, continue to receive a dose of more than 0.1 mSv (10 mrem) in any week or to enter a controlled area (see 2.4) (Reg 8) (see also 2.3.1 regarding the investigation of the overexposure). However, where an annual limit has been exceeded these restrictions may be removed if, with the agreement of the appointed doctor (see 3.8) and after the radiation protection adviser (see 2.1.6) has been consulted, a certificate of exceptional exposure has been obtained (see 2.2.10) (Regs 8 and 10 and AC1/55). The conditions for entering controlled areas (see 2.4.10) will still apply and the person must be a volunteer (Reg 10).

1.3.3 A person for whom a certificate of planned special exposure or exceptional exposure has been granted must not receive, in the calendar year, a dose greater than twice any dose limit applicable to him (Reg 10).

1.3.4 It is unrealistic to specify dose limits for emergency (unplanned) exposures where justification will be the rescue of individuals or the prevention of the exposure of a large number of people. In these cases the acceptability of the dose will depend on the importance of the objective.

1.4 Dose limits for members of the public

1.4.1 The dose limits for members of the public are one-tenth of the annual limits given in Table 1.1. They apply to radiation from many sources other than natural background; there is no agreed proportion which applies to that from research and teaching. The term 'members of the public' includes visitors.

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*In Northern Ireland, the Department of Manpower Services.

1.4.2 Although the regulations specify the same dose limits for all adult workers, it is expected that those whose work is not concerned with ionising radiation will not receive doses exceeding the dose limits for members of the public as a result of their proximity to radiological work (ACI/29).

2 Administrative measures for radiological protection

2.1 Responsibility and organisation

2.1.1 At research establishments the ultimate responsibility for protection measures lies with the controlling authority.* The authority is responsible for the protection of all workers (whether or not they are employed by the Authority), and of members of the public who may be affected by the work. This responsibility derives from Sections 2(1), 3(1), and 4 of the Health and Safety at Work etc. Act 1974†,(7) and cannot be devolved. At universities, polytechnics and colleges, the controlling authority has, in addition, a responsibility for protecting its students (Section 4 of the Act). The controlling authority is the 'responsible person' as defined in the Ionising Radiations Regulations 198-.(10). These regulations distinguish between the responsibilities of the responsible person and the employer and this is explained in the approved code; apart from the general advice given in 2.1.2 and 2.1.3, this distinction is not made in these guidance notes. (See Reg 3 and ACI/7–13, 23, 30, 48 and 102 regarding co-operation between the employer and the responsible person.)

2.1.2 Where contractors are involved, Section 4 of the Act (Article 6 of the Northern Ireland Order) says that such people are to be treated as if they were 'persons having control' of the matters covered by their contractual obligations. As such they have a duty to take measures to ensure that their undertaking is safe and without risks to health but only to the extent to which they are obliged by their contracts. The controlling authority will also have its own duties to discharge in respect of Section 4 and therefore when contractual arrangements are entered into it will be necessary to ensure that each party fully understands the extent of its own responsibility. Such arrangements will be necessary in respect of, for example, maintenance contractors and agency staff.

2.1.3 A division of responsibility may also be necessary in respect of Section 6 of the Act (Article 7 of the Northern Ireland Order) which deals with the general duties of manufacturers, importers and suppliers as regards articles for use at work. For example, the point at which responsibility for new equipment passes to the controlling authority will need to be understood since an employer's general duties under Section 2 of the Act extend to the provision of plant. This is particularly important if on the basis of a written undertaking the controlling authority wishes to relieve the supplier, contractor, etc., from the duty imposed by Section 6. Some arrangements may also be necessary when equipment is transferred from one establishment for use in another. The duties of manufacturers, importers and suppliers under Section 6 of the Act are extended by Regulation 34 to ensure that radiation protection is a factor designed and built into the articles supplied (ACI/227).

2.1.4 To assist in the discharge of its duty it is essential that the controlling authority provides an administrative organisation in which the immediate responsibility for radiological safety at each level of control is clearly defined. An example of such an organisation is given in Appendix 2. At larger establishments, with many sources of radiation, it is recommended that a radiation safety committee should be set up.

2.1.5 In every department where radioactive substances or machines capable of generating radiation are present, the responsibility for ensuring that regulations, the approved code of practice and these guidance notes are observed inevitably lies with the head of the department, having regard to arrangements made by the radiological safety organisation of the institution. When field work is carried out, the responsibility for observance lies with the head of the department concerned.

2.1.6 If the controlling authority requires advice on radiation safety or on methods of complying with the regulations, it should appoint a radiation protection adviser; in particular one should be appointed if it is necessary to designate any area, which people enter, as a controlled area (see 2.4) (ACI/78). He must be suitably qualified and experienced in radiation protection in relation to the work done at the establishment and he must be informed of the scope of the advice that he may be called upon to give (Reg 13). More than one radiation protection adviser should be appointed if the range of relevant duties or the complexity of the processes so warrants (AC1/80). Advice on the selection of a radiation protection adviser may be obtained from [to be filled in]. The radiation protection adviser should be provided with adequate accommodation, equipment and supporting staff (AC1/81). He should regularly visit the departments to which he has been appointed, to review, in consultation with the heads of departments, the protection measures laid down. Subjects on which his advice should be sought are listed in AC1/82.

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*See Appendix 7.

†In Northern Ireland, Articles 4(1), 5(1) and 6 of the Health and Safety at Work (Northern Ireland) Order 1978(8).

2.1.7 To provide immediate special supervision and to ensure that protection measures are carried out, one or more persons with a sound working knowledge of radiological protection in relation to the work which they are to supervise should be appointed as radiation protection supervisors (AC1/93). It is considered essential to have a radiation protection supervisor (analagous to the Departmental Radiological Safety Officer of the previous code of practice) in every department where radiation sources are used. The head of department should be consulted about the appointment; it should be from among the full-time employees in the department (AC1/93). The advice of the radiation protection adviser should also be sought (AC1/95). The radiation protection supervisor may need special training (see 2.7.3). Where radiation sources in his care are used outside the department in an area for which there is no separate radiation protection supervisor, protection measures remain his concern. He should report immediately to the head of department on unsatisfactory conditions and propose measures to remedy them. The head of department, in consultation if necessary with the radiation protection adviser, should decide what action is to be taken. The appointment of radiation protection supervisors should be reviewed periodically so that the controlling authority is satisifed of the continued suitability of the persons chosen. Appointments, and termination of appointments, should be in writing and the names of the radiation protection supervisors should be displayed in the areas for which they are appointed (AC1/93 and 96).

2.1.8 If classified persons (see 2.5) are to be employed, the controlling authority must arrange for their medical surveillance by an 'appointed doctor' or by an employment medical adviser (Reg 19). An 'appointed doctor' means a registered medical practitioner, possibly, but not necessarily, on the staff of the establishment, who has been appointed in writing by the Health and Safety Executive. An employment medical adviser is one who has been appointed under Section 56 of the Health and Safety at Work etc. Act 1974.* The functions of the 'appointed doctor'† are described in Chapter 3.

2.1.9 It is essential that the controlling authority makes arrangements for an effective system of internal communications. In addition to the persons mentioned above, the safety representatives must be provided with information in accordance with the Safety Representatives and Safety Committees Regulations 1977(9); this would include advice given by the radiation protection adviser and copies of investigation reports.

2.2 Notifications and authorisations

2.2.1 The controlling authority must give notice to the Health and Safety Executive‡ (normally 28 days in advance) before commencing work involving 'notifiable quantities§ of radioactive substances, having a concentration exceeding 100 Bq g^{-1} (2.7 nCi g^{-1}), or the operation of a machine or apparatus in which charged particles are accelerated through a potential differences of more than 5 kV (Reg 5(1)). If such work is already being done when the Ionising Radiations Regulations come into force the Health and Safety Executive‡ must be notified within 28 days (Reg 5(3)). Timepieces and instruments containing radio-luminescent paint and most television receivers, monitors and visual display terminals are exempt (Schedule 5 of the regulations). Certain particulars have to be given and Form No 0011 must be completed in accordance with the notes attached to it (Reg 5(1) and AC1/16). Some additional particulars may be asked for by the Health and Safety Executive. There will normally be no need to notify changes in the work.

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*In Northern Ireland, Article 48 of the Health and Safety at Work (Northern Ireland) Order 1978

†This term will be used in these guidance notes to include an employment medical adviser.

‡As enforcing authority of the Health and Safety at Work etc. Act for the type of premises where work covered by these guidance notes is carried out. In Northern Ireland, the Department of Manpower Services must be notified.

§Minimum notifiable quantities are shown in column 3 of Table 2.1.

‖Obtainable from the Health and Safety Executive.

In Wales or Scotland, the respective Secretary of State. In Northern Ireland, the Department of the Environment for Northern Ireland.

2.2.2 The name, qualifications, experience and status of the radiation protection adviser who has been appointed, and the scope of the advice that he may be called on to give, must be notified to the Health and Safety Executive (Reg 13(3)). If the radiation protection adviser is a corporate body or partnership the same particulars of individuals who would give that advice should be supplied (ACl/83). Any changes should be notified.

2.2.3 The Controlling Authority must apply, under Section 1 of the Radioactive Substances Act 1960(2), to the Secretary of State for the Environment* for registration of premises where radioactive substances are to be kept or used. The certificate of registration will specify certain conditions, normally including a requirement that the keeping and use of registered sources or registered substances is supervised by a person(s) who will ensure that the conditions are complied with. There are a number of exemption orders which give conditional exemption from registration for small quantities of radioactive materials. These include those referred to in 15.3.2.

2.2.4 The controlling authority must apply to the Secretary of State for the Environment for authorisation under Sections 6 and/or 7 of the Radioactive Substances Act 1960 if it is likely to be necessary to dispose of, or accumulate, non-exempt radioactive waste. There are a number of exemption orders which give conditional exemption from authorisation (see 15.3).

2.2.5 Copies of the certificates of registration or authorisation must be kept posted on the premises (Section 11 of the Radioactive Substances Act 1960).

2.2.6 The Health and Safety Executive† must be notified:

(a) following any incident in which radioactive material of activity exceeding that shown in column 2 of Table 2.1 has been dispersed other than by a route specified in an authorisation to dispose of radioactive waste (Reg 6(1)). This refers to dispersal into the workplace or general environment; dispersal inside a fume cupboard or glove box would therefore not necessarily be notifiable (ACl/19).

(b) following a fire or explosion involving an activity exceeding that shown in column 2 of Table 2.1 (Reg 6(1)). Notification is required whether or not any material has been dispersed.

(c) if a sealed source or unsealed radioactive material of activity exceeding that shown in column 3 of Table 2.1 has been reported lost or stolen and not found or recovered within 24 hours (Reg 6(3)).

Table 2.1 Activities above which notification is required

1 *Radiotoxicity class‡*	2 *Dispersal, fire, explosion*	3 *Loss*
1	3 MBq (80 Ci)	5 kBq (140 nCi)
2	300 MBq (8 mCi)	50 kBq (1.4μCi)
3	30 GBq (800 mCi)	500 kBq (14μCi)
4	3 TBq (80 Ci)	5 MBq (140μCi)
5	300 TBq (8 kCi)	Unlimited

The activities in column 3 are the 'minimum notifiable quantities' in connection with Reg 5(4)
[The National Radiological Protection Board is reviewing the activities shown in this table.]

If radionuclides of more than one class are involved, notification is required if the sum of their activities relative to the maximum value for their class exceeds unity.

2.2.7 The Secretary of State for the Environment must be notified (through the Radiochemical Inspectorate§) if any registered source or registered substance is lost or stolen or if a registered source is broken or damaged or radioactive material has escaped from it (standard conditions of registration under the Radioactive Substances Act 1960).

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*In Wales or Scotland, the respective Secretary of State. In Northern Ireland, the Department of the Environment for Northern Ireland.

†In Northern Ireland, the Department of Manpower Services.

‡See Schedule 2 to the Regulations.

§Or, as appropriate, the Environment Protection Unit, Welsh Office, HM Industrial Pollution Inspectorate for Scotland, the Alkali and Radiochemical Inspectorate for Northern Ireland.

2.2.8 The police must be notified of any loss or theft which is notifiable to the Secretary of State for the Environment (or the corresponding Secretary of State or Department) or to the Health and Safety Executive* (standard conditions of registration and Reg 6(3)).

2.2.9 The Health and Safety Executive must be notified if a worker, student or member of the public has received an overexposure or a suspected overexposure (Reg 9(4) and (5)). The controlling authority must notify HSE as soon as possible after it has itself been informed (unless an immediate investigation shows that there had in fact been no overexposure) and later send the results of the detailed investigation (see 2.3.1).

2.2.10 A planned special exposure may be given only if the Health and Safety Executive has issued a certificate of planned special exposure (see 1.3.1). The special restrictions placed on a person who has received an overexposure may be removed only if HSE has issued a certificate of exceptional exposure (see 1.3.2).

2.2.11 If radioactive substances are to be administered to animals for the purposes of research, the controlling authority must ensure that each person who administers holds, where necessary, a Home Office licence for carrying out experiments on living animals (Cruelty to Animals Act 1876)(6). A licence will, in general, be needed for experiments on vertebrates which might cause pain. Administration to human subjects for research is considered in the medical and dental guidance notes. (123)

2.2.12 Under the Nuclear Installations Act 1965,(3) a licence‡ is required before work can be begun on nuclear reactors (including zero energy reactors), critical experiments, sub-critical experiments using enriched uranium and certain other installations where enriched uranium and irradiated nuclear fuel are handled or stored. The conditions of the licence require inspection and testing during construction and the submission of detailed operating procedures in the interests of safety. At the earliest possible stage in planning any work for which a licence under the Act may be required, the controlling authority should consult the Nuclear Installations Inspectorate of the Health and Safety Executive.

2.2.13 A hazard survey report must be submitted to the Health and Safety Executive* if substantial quantities of radioactive materials (see Table 2.2) are used or stored unless the site is licensed under the Nuclear Installations Act 1965 (Reg 33). This requirement will rarely require any action at research or teaching establishments.

Table 2.2 Quantities above which a hazard survey is required

Radioactive material	*Quantity*
Class 1	500 GBq (13.5 Ci)
Classes 2 and 3	5 TBq (135 Ci)
Classes 4 and 5	50 TBq (1.35 kCi)
Special form*	1 PBq (27 kCi)
^{239}Pu, ^{233}U	150 g of Pu or U
^{235}U	500 g of 1-5% enriched U or 250 g of 5% enriched U

*As defined in the International Atomic Energy Agency's Transport Regulations(65)

2.2.14 Educational establshments of the types listed in Administrative Memorandum 2/76(110)† require the approval of the Secretary of State for Education and Science,† before carrying out 'high level work' in accordance with these guidance notes. This may be work with radioactive sources where the Schools etc. Exemption Orders (27,29) do not apply and/or with X-ray equipment.

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*In Northern Ireland, the Department of Manpower Services.

†In Wales, the approval of the Secretary of State.
In Scotland, Circular No. 689(112) and the approval of the Secretary of State.
In Northern Ireland, an un-numbered circular(113) and the approval of the Department of Education for Northern Ireland.

‡The licensing provisions of tne Nuclear Installations Act 1965 do not extend to the UKAEA or to Government Departments.

2.3 Investigations

2.3.1 If any person thinks that he or another person has received a radiation dose exceeding any of the relevant dose limits, he must inform the controlling authority (Reg 9(2)). The controlling authority might alternatively learn of the overexposure of one of its staff or students through a communication from the approved laboratory (see 4.1.6). Unless an immediate investigation shows that the report was false, the controlling authority must arrange for a detailed investigation after first notifying HSE (see 2.2.9) and (if the person is a worker or student) the appointed doctor (see 3.7) (Reg 9). The investigation should be made in consultation with the radiation protection adviser and its objectives should be:

(a) to obtain the best estimate of the dose or intake,

(b) to determine (if a significant dose has been received) what action is necessary to prevent a recurrence,

(c) to indicate whether any persons need to be classified (see 2.5).

(ACl/48 and 49)

To assist in achieving objective (a), it may be advisable to take a blood sample from the affected person and send it to an approved laboratory* able to carry out chromosome examinations and the estimation of biological dose.† The results of the investigation must be sent to HSE, the person affected and (if the person is a worker or student) the appointed doctor (Reg 9). The estimated dose must be entered in the dose record where there is such a record (see 4.1.6) (Reg 9(6)); if this affects an existing entry in the record, approval of a special entry will be required (see 4.1.9). A record of the investigation must be kept for 50 years (Reg 9(6)).

2.3.2 In the case of a person for whom a certificate of planned exposure or of exceptional exposure has been issued, the action described in 2.3.1 should be taken if it is thought that he has received a dose of more than twice an annual dose limit.

2.3.3 Where the dose records (see 4.1.6) indicate, or there is other reason to think, that a group of persons or an individual has received an effective dose during the calendar year exceeding 15 mSv (1.5 rem) the controlling authority must arrange for an investigation by the radiation protection adviser to ensure that the doses are as low as reasonably practicable (Reg 7 and ACl/24 and 25). This investigation should be carried out as soon as possible after the receipt of the particular dose record or of the effective dose exceeding this level; an interim report should be made if it is not possible to complete the investigation within three months (ACl/26). Where the working situation has previously been investigated for this purpose the previous investigation should be reviewed. The radiation protection adviser should report the results of his investigation or review to the controlling authority, and if appropriate make recommendations for any reasonably practicable measures that would reduce future exposures. In general, where measures have already been taken to reduce dose to as low as reasonably practicable, further recommendations for reduction would not be expected. If the controlling authority cannot accept any such recommendations that are made it should state its reasons to the radiation protection adviser in writing (ACl/27) with a copy to the safety representative (see 2.1.9).

2.3.4 The Health and Safety Executive will be informed about doses exceeding 30 mSv (3 rem) in a calendar quarter (see 4.1.6) and may initiate a special enquiry whether or not a dose limit has been exceeded.

2.3.5 Other types of investigation are described in 2.4.12. 4.1.8, 4.1.9 and 16.4.5.

2.4 Designation of areas

2.4.1 The controlling authority must designate as a 'controlled area' any area under its control where any person might receive a dose or committed dose, other than from natural background, exceeding three-tenths of any of the annual dose limits for adult workers (Reg 12(1)). Where conditions are such that persons might receive more than one-tenth but less than three-tenths of the annual dose limits the controlling authority must designate that area as a 'supervised area' unless it has been designated as 'controlled' (Reg 12(1)). Small areas, accessible only to the hands, might need to be designated.

2.4.2 If the dose rate in an area is always less than 7.5 μSv h^{-1} (0.75 mrem h^{-1}) and there is no risk of internal exposure the area need not be a controlled area; if the dose rate is always less than 2.5 Sv h^{-1} (0.25 mrem h^{-1}) it does not need to be a supervised area. If the dose rate is higher than this at any time, or unsealed radioactive substances are present, the controlling authority should consult the radiation protection adviser in order to determine whether the area needs to be designated (AC1/58). Alternatively (e.g. if there is no radiation protection adviser), the area should then be designated without consultation; however, if a controlled area is occupied it is necessary to appoint a radiation protection adviser (see 2.1.6). An assessment is necessary for all new installations and should be repeated periodically, or after a significant change in equipment or methods of work, as recommended by the radiation protection adviser.

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*[It is suggested that the laboratory should be approved by HSE.]

†The National Radiological Protection Board provides this service.

2.4.3 The doses which might be received are those which would be received by a person, not wearing protective clothing, who spends the whole of his working time (usually considered to be 40 hours per week and 50 weeks per year) in the area (Reg 12(1)). The intermittent operation of radiation sources, e.g. in radiography, may, however, be taken into consideration by the radiation protection adviser.

2.4.4 Other factors which may be taken into account by the radiation protection adviser are listed in AC1/60. In areas where unsealed radioactive substances are used he will normally base his decision on the activities of the radionuclides which will be present in relation to their ALIs or radiotoxicity class but he may also wish to include other factors (see 12.2.5 and Appendix 1).

[The National Radiological Protection Board does not consider that it is normally appropriate to use surface contamination as a designation criterion (see AC1/58). Derived limits for surface contamination are given in Appendix 4 and should be regarded as action levels for decontamination (see also 12.8.12).]

2.4.5 The full extent and precise location of controlled or supervised areas should be described in the local rules (see 2.6) by reference, so far as is practicable, to fixed features such as walls and other barriers; for mobile sources the description should refer to distances from the source (AC1/64 and 65). An area larger than strictly necessary may be designated as a controlled or supervised area in order to make use of natural boundaries; for a controlled area this is not always acceptable as it might result in the inclusion in the area of people who would otherwise be outside. A supervised area will not be needed if the whole area is controlled.

2.4.6 Where there might be any doubt, the local rules should explain whether an area has been designated on account of external radiation or of internal hazard. Occasionally, an area may need to be designated for both reasons simultaneously.

2.4.7 Signs should indicate the position of radiation sources within controlled and supervised areas.

2.4.8 In order to restrict access to a controlled area there should, where reasonably practicable, be an effective barrier at its boundary. Notices should be displayed, particularly at entry points, warning that it is a controlled area (AC1/67). A notice should incorporate a radiation warning sign (see Appendix 3) and give any necessary information including the reason why the area is a controlled area, e.g. 'X-radiation', 'intake hazard'.

2.4.9 An area does not necessarily have to remain continuously designated as a controlled area. If an X-ray set has been isolated from the electricity supply or if all radioactive sources have been removed (e.g. to a store) the designation may be temporarily withdrawn. This will not normally apply to a laboratory where unsealed radioactive substances are used because of the difficulty in ensuring that it has been sufficiently decontaminated; it might, however, become temporarily a supervised area.

2.4.10 Access to controlled areas must be restricted to classified persons (see 2.5), workers and students who are covered by a 'scheme of work' and visitors as permitted by the local rules (Reg 12 (3)). No person who has received an overdose is allowed to enter a controlled area unless a certificate of exceptional exposure has been issued (see 1.3.2). Pregnant women should not enter controlled areas as classified persons but may do so under a scheme of work.

2.4.11 Entry under a scheme of work is appropriate if the controlling authority is satisfied that the operating and working conditions and the system of control and instruction are such that a person working in accordance with the scheme is most unlikely to receive doses more than three-tenths of the annual dose limits for adult workers. The wearing of protective clothing, when it is a condition of the scheme of work, may be taken into account. The scheme of work should be drawn up in consultation with the radiation protection adviser and should take account of any other work with ionising radiation by persons to whom the scheme applies, such as entry of other controlled areas (AC1/70).

2.4.12 The scheme of work should include personal monitoring of all, or a representative sample of, the persons covered (see 4.1.14) or some other way of monitoring their exposure, possibly including control of the time they spend in the area (AC1/71). Records should be kept for two years (AC1/72).

2.4.13 If this monitoring indicates that any person might receive doses greater than three-tenths of the annual dose limits an investigation should be held; the scheme of work should then be modified and/or persons who are operating under it designated as classified persons (AC1/73).

2.5 Designation of classified persons

2.5.1 The controlling authority must, after consulting the radiation protection adviser, determine in respect of all occupationally exposed persons aged 18 years or more for whom it is responsible, whether or not they shall be identified as 'classified persons'; these are persons whose work or training involves exposure to ionising radiations to such an extent that the resulting annual doses might exceed three-tenths of any of the dose limits (Reg 14). It should be considered that any worker or trainee who enters a controlled area, except under a scheme of work, might receive a dose exceeding three-tenths of a dose limit and so he should be designated as a classified person (AC1/85).

2.5.2 Though it may be necessary to 'classify' a person who spends a considerable part of his time in a controlled area, the alternative procedure of a scheme of work should be considered, particularly for those who spend much shorter times in these areas. This will avoid unnecessary classification.

2.5.3 A person may be designated as a classified person only if he has been certified fit (possibly subject to conditions) by the appointed doctor (see 3.3). He may be employed as a classified person only when arrangements have been made for assessing his individual radiation dose (see 4.1).

2.5.4 In view of the lower dose limits for persons under the age of 18 years, they cannot be classified persons. During pregnancy women should be restricted to working conditions which would not require them to be 'classified' in order to ensure that the dose limit to the fetus is not exceeded.

2.5.5 A person should cease to be designated as a classified person if an entry is made in the health record (see 3.9) that he becomes unfit to be designated (AC1/89). He may also cease to be designated when he leaves the employ of the controlling authority or completes his training course. Otherwise he should remain designated throughout the calendar year although personal monitoring may be stopped if he ceases to enter controlled or supervised areas. His exposure to ionising radiation should be reviewed at the end of the year, in consultation with the radiation protection adviser; designation may be withdrawn if it is considered most unlikely, because of changed circumstances, that he will receive doses greater than three-tenths of the annual dose limits.

2.6 Local rules

2.6.1 The controlling authority must arrange for local rules to be drawn up (Reg 15(1)). This should be done in consultation with the radiation protection adviser and the radiation safety committee.

2.6.2 It is essential that the rules set out clearly and precisely the procedure in force in each establishment, department or laboratory and the names and duties of the persons who are concerned with health and safety, such as the radiation protection adviser, the radiation protection supervisor(s) and the appointed doctor.

2.6.3 The local rules must include a description of each controlled or supervised area (see 2.4.5) (Reg 12 (3)).

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2.6.4 The essential features of any scheme of work should be incorporated in the local rules (AC1/69). The local rules should also include ways of ensuring that if visitors enter controlled areas the doses they receive are as low as is reasonably practicable and in any case below the dose limits for members of the public (AC1/74). It may be necessary to distinguish between a visitor on one occasion only and a person who makes frequent visits.

2.6.5 The local rules should also cover emergency conditions (see 2.10, 16.1.4 and 16.2.4).

2.6.6 Local rules may be specific to a particular laboratory or department or may apply throughout the whole establishment.

2.7 Instruction and training

2.7.1 The controlling authority must ensure that all workers and students for whom it is responsible are adequately instructed about the hazards they may meet and the precautions to be observed; where necessary special training must be given (Reg 16 and AC1/98-102). Controlling authorities should be advised in these respects by the radiation protection adviser (AC1/82) and the radiation safety committee.

2.7.2 All visitors to controlled or supervised areas should be informed of any precautions which they need to observe (AC1/103).

2.7.3 The controlling authority should ensure that the radiation protection supervisor(s) receives any training needed to fit him for his duties. He should be instructed in procedures for management of contaminated persons (AC1/181) and on dealing with incidents; his duties include the investigation of incidents and overexposures of workers, students or members of the public which have to be notified to HSE (AC1/94) (see 2.2.6 and 2.2.9). His knowledge will need to be kept up to date.

2.7.4 It must be impressed on every individual working with radiation sources that he has a duty to protect himself and others from any hazard arising from his work (HSW Act 1974, Section 7).* He is therefore not permitted to expose himself or others to ionising radiation to a greater extent than is reasonably necessary for the work he is engaged on. He must also not interfere with or misuse anything provided in the interests of radiological safety (HSW Act 1974, Section8).†

2.7.5 It is essential that every member of the staff and every student is familiar with the responsibilities and precautions imposed on him by regulations, the approved code of practice and guidance notes and by the local rules. The controlling authority will therefore need to ensure that he reads either the relevant sections of the guidance notes and of the local rules or a suitable statement which explains clearly his own responsibilities, and that he is made aware of any subsequent change.

2.8 Planning of installations

2.8.1 When planning a new radiological installation or laboratory or modifying an existing one, authoritative advice should be obtained about the suitability of the location, design and construction of the premises and equipment, and about the arrangements for the storage of radioactive substances and for the disposal of radioactive waste. This advice should be sought from the radiation protection adviser or from an organisation such as the National Radiological Protection Board or, in Northern Ireland, the Northern Ireland Radiation Protection Service (see 15.2.2 regarding advice on waste disposal).

2.8.2 When planning a new radiological installation, account should be taken of the expected work-load of any equipment, the orientation factors of the barriers, and, if desired, the occupancy factors of the adjacent areas (although the latter will not affect area designation). Allowance should be made for possible future increases in these factors, for changes in the outputs or positions of radioactive sources, and for future modifications in technique. Planning must ensure that no area outside the controlling authority's control would, if it were under control, need to be designated as a controlled area (Reg 12(2)).

2.8.3 The installer of equipment must make a critical examination of the way it has been installed before it is used for the first time and must supply the user with adequate information to enable the equipment to be properly used (Reg 34(2)). The installer may use the services of his own radiation protection adviser in carrying out the examination but the radiation protection adviser for the establishment should be consulted when the new installation is accepted.

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*In Northern Ireland, the Health and Safety at Work (Northern Ireland) Order 1978, Article 8.

†In Northern Ireland, the Health and Safety at Work (Northern Ireland) Order 1978, Article 9.

2.9 Registration of work

2.9.1 No project which requires the use of radioactive materials or electrically generated radiation, or which may give rise to adventitious radiation, should be started without the knowledge of the head of the department and of the radiation protection supervisor. This need not apply to the use of equipment described in 9.3.2.

2.9.2 Before sanctioning the project the head of the department will need to consider various aspects including the following:

(a) the justification for the radiation doses which may be incurred (see 1.1.2);
(b) the suitability of the installation or laboratory (see 2.8);
(c) the knowledge and experience of the worker or student, the supervision available and the possible need for further training in radiological protection (see 2.7.1);
(d) confirmation that the project can be carried out within the terms of existing registrations and licences, (see 2.2);
(e) assurance that radioactive waste likely to arise can be disposed of (or accumulated) within authorised limits (see Chapter 15);
(f) the effect on the designation of the area (see 2.4);
(g) the possible need for the worker or student to be 'classified' or work under a 'scheme of work' (see 2.5 and 2.4.11);
(h) the adequacy of the local rules in relation to the project (see 2.6);
(i) the effect on contingency plans (see 2.10).

2.9.3 The head of the department may need to consult the radiation protection adviser and/or the radiation safety committee and should do so if the project involves a new type of work or a substantial extension of existing work.

2.9.4 The controlling authority should therefore institute a system of registration of work. It may think it appropriate to appoint referees.

2.9.5 These recommendations apply to medical and dental research which does not involve human subjects. The medical and dental guidance notes include safeguards for projects in which human beings are irradiated.

2.10 Contingency planning

2.10.1 The controlling authority must make contingency plans if significant radiation exposure resulting from an accident or incident can be reasonably foreseen, the arrangements being designed to limit such exposure (Reg 31(1)). Any exposure which could lead to a dose in excess of a dose limit should be considered significant (ACl/221). In some cases special controls, designed to be used in emergencies, can be built into equipment but operational plans will usually be needed. Details must be included in the local rules and workers who are concerned must be given suitable instructions (Reg 31(2)). Guidance on emergency procedures is given in Chapter 16.

2.10.2 Where radioactive substances are used, arrangements should be made with the chief fire officer* for the local fire brigade to visit the establishment to obtain information about the layout of the premises and about warning measures and symbols. The chief fire officer should also be consulted about the suitability, in relation to radiation hazards, of fire fighting equipment installed on the premises or which might be brought to the site.

2.10.3 There should be readily available an up-to-date list of all places in the establishment where there are radiation hazards, showing the exact location of and the means of access to all rooms likely to contain substantial amounts of radioactive substances. The chief fire officer should be given a copy of this list.

2.10.4 Arising out of consultations with the chief fire officer, it is essential that a section of the local rules is drawn up which details the procedure to be followed in the event of a fire involving radioactive substances and that these rules are read by all persons who may be concerned. The rules should mention specifically any place where there are radioactive substances which, in the event of a fire, could cause inhalation or contamination hazards to those engaged in fire fighting and to those entering the area after the fire. In general, the importance of fighting the fire outweighs minor radiation hazards.

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*In Scotland, the firemaster.

2.11 Records

2.11.1 This section is an index to the records which are required by regulations or the approved code of practice, or which are recommended as essential or desirable. The controlling authority must or should, as the case may be, arrange for these records to be kept. The sections whose numbers are given should be referred to for details.

2.11.2 The following records are required by the Ionising Radiations Regulations or by certificates of registration or authorisation issued under the Radioactive Substances Act 1960 or are called for by the approved code of practice:

Health record (3.9)	50 years*
Radiation dose record (4.1.6-10)	50 years*‡
Dose assessment report (4.1.14)	2 years†
Record of dose assessment (2.4.12)	2 years†
Schedule of personal dosimetry (4.1.17)	Not specified
Monitoring of controlled and supervised areas (4.3.5 and 12.7.2)	2 years*
Testing of monitoring instruments (4.4.6)	2 years*
Leakage tests (14.7.5)	3 years†
Record of radioactive materials (14.9.2)	Not specified
Disposal of radioactive waste (15.1.1, 15.2.8 and 15.3.1)	Not specified
Investigation of overexposure of worker, student or member of the public (2.3.1)	50 years†
Maintenance of exposure containers	Not specified

*after last entry

†from date of test/report

‡to be kept by approved laboratory

2.11.3 The following records are considered essential:

Daily records of movements of closed sources (15.9.3)
Details of incidents involving injury with the possibility of radioactive contamination (12.8.4)
Investigation of emergencies (16.4.5)

2.11.4 The following records should be kept:

Investigation of doses (ALARA) (2.3.3)
Cases of contamination of skin or hair (3.11)
Monitoring of other areas (12.7.2)
Record for radionuclide generators (14.9.5)

2.11.5 It is also advisable to keep copies of notifications, reports from the radiation protection adviser, dose summaries and termination records, certificates for source loading, and any other papers likely to be needed in a subsequent entry.

3 Medical surveillance

3.1 Medical surveillance by the 'appointed doctor'* must be arranged for all classified persons and for other workers or students if they receive an overdose (Reg 19(1) and (3) and AC1/119-121). Guidance for appointed doctors on their duties in connection with ionising radiation is given in Guidance Notes for Appointed Doctors(122) issued by the Health and Safety Executive.

3.2 The persons concerned must present themselves for medical examinations and make available to the appointed doctor information about their health (Reg 19(7)).

3.3 Before a person is designated as a classified person for the first time, or redesignated after an interval and there is no longer a valid entry in the health record (see 3.9), he should be medically examined and certified by the appointed doctor as fit to be designated (AC1/122). The examination is unnecessary if the person has been declared fit by another appointed doctor during the preceding 14 months and a copy of the previous certificate has been obtained. This certificate may relate either to a medical examination or to a health review (see 3.6). The examination may also be dispensed with if, on the day that the regulations come into force, the person is already employed in work which would require him to be a classified person (AC1/123).

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*See footnote to 2.1.8.

3.4 The pre-employment medical examination may include an enquiry into the person's medical history including all known previous exposures to ionising radiation resulting either from his employment or from medical examination or treatment. The form of the examination is otherwise at the discretion of the appointed doctor. Information about the working environment should be made available to the appointed doctor so that he can take account of this in assessing fitness and he must be allowed to inspect the workplace if he asks to do so (Reg 19(8)). He must also be given copies of the relevant dose summaries (see 4.1.7) and allowed to see other records (Reg 19(6) and (9)).

3.5 If the classified person is declared fit subject to conditions, the controlling authority and the worker must observe these conditions (Reg 19(5)). The worker has rights of appeal against a medical decision, to be exercised within 3 months (see Reg 19(10)). Appeals will come before a medical tribunal.

3.6 The state of health of each classified person should be reviewed annually by the appointed doctor (ACl/124 specifies that intervals should not exceed 14 months), or more frequently if specified by the doctor, to determine whether he remains fit for his duties. The form of the review will depend on the type of exposure and the doses received as well as on the classified person's state of health. In some cases the appointed doctor may recommend that medical surveillance continues after the person concerned ceases to be a classified person.

3.7 The appointed doctor must be informed if an overexposure of a worker or student is suspected, whether or not the person concerned is a classified person (see 2.3.1). A special medical examination should be made if the investigation confirms that the dose received may have been more than twice an annual dose limit for adult workers (ACl/125). The appointed doctor should consider whether any remedial treatment should be provided following intake of radioactive substances exceeding the relevant ALI.

3.8 If a person has received an overexposure, the agreement of the appointed doctor should be obtained before the Controlling Authority makes an application for a certificate of exceptional exposure (see 2.2.10).

3.9 The Controlling Authority must keep a health record for every person under medical surveillance, containing the results of all medical examinations and periodic review of health in respect of radiological protection (Reg 19(2)). It must indicate whether a person is fit, fit subject to conditions, or unfit to be designated as a classified person (ACl/127). An official form obtainable from HM Stationery Office, or a form which has the same headings, should be used (ACl/126). Copies of previous certificates referred to in 3.3 should also be kept in the health records. An entry in the health record remains valid for 14 months (unless the appointed doctor specifies a shorter period) or until it is superseded by a further entry (ACl/128). Health records, which are to be distinguished from the doctor's clinical records, must be retained for 50 years after the last entry (Reg 19(2)).

3.10 The appointed doctor should be consulted on the provision of suitable first-aid facilities and on the training of persons in charge of first aid. First aid may be required following contamination of the skin or hair particularly if the skin is broken (see 12.8.4) and if radioactive substances are accidentally inhaled or ingested. However, the appointed doctor should be informed without delay.

3.11 Where the contamination of the skin or hair cannot be reduced by first-aid measures to a level below that given in Appendix 4 a record should be made. The record should indicate the cause of the contamination, the action taken to deal with it, and the length of time during which the 'excess' contamination lasted.

4 Operational measures for radiological protection

4.1 Personal monitoring

4.1.1 The dose of ionising radiation received by each classified person must be systematically assessed and the controlling authority must make arrangements for personal monitoring to be carried out by an approved laboratory* (Reg 17(1) and (4)).

4.1.2 Where exposure is from external sources (other than low energy beta sources with no significant bremsstrahlung emission) this monitoring should be by means of one or more dosemeters worn on an appropriate part or parts of the body. If an immediate indication of the dose received is necessary, a direct-reading device, such as a pocket ionisation chamber, may also be worn but the requirements for personal dosimetry do not apply to that type of monitoring. An additional dosemeter sensitive to fast neutrons will be required if the annual dose from this component of the total dose is liable to exceed one-tenth of a dose limit (ACl/108). Radiations such as low energy beta-rays from C-14 which cannot easily be measured by individual dosemeters should be checked by environmental monitoring. The advice of the radiation protection adviser should be sought on the most appropriate measurement(s) and type(s) of dosemeter for each classified person (ACl/111). Dosemeters are supplied by the approved laboratory.

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*The addresses of approved laboratories may be obtained from the Health and Safety Executive or in Northern Ireland, the Department of Manpower Services.

4.1.3 Each dosemeter is normally worn for four weeks but if the workload is low the monitoring period may be increased to eight weeks. The length of each monitoring period should depend on the doses likely to be received during the period (ACl/106). Dosemeters should be returned promptly after use to the approved laboratory for dose assessment and replaced with new ones.

4.1.4 A person who has been issued with a dosemeter must wear it as instructed all the time that he is in a controlled or supervised area and return it at the end of the period (Reg 17(3) and ACl/110). Care should be taken to prevent the dosemeter, while not being worn, from being exposed inadvertently to ionising radiation. An individual dosemeter should normally be worn on the trunk at chest or waist height, the latter being recommended in the case of women of reproductive capacity. It may then be interpreted as monitoring the dose to the whole body. However, if there is any reason to suspect that doses to other parts of the body may exceed three-tenths of the appropriate dose limit, it may be necessary to arrange for the wearing of additional dosemeters.

4.1.5 A dosemeter should be worn on a finger or wrist while working with small sealed sources or unsealed radioactive material if the dose to the hands is liable to exceed three-tenths of the dose limit shown in Table 1.1. It may also be advisable during alignment procedures in X-ray crystallography (see 7.5.4). A trial programme of monitoring may be desirable to determine whether routine monitoring is necessary.

4.1.6 The approved laboratory will maintain a dose record for each classified person and keep it for 50 years after the last entry. Summaries of the dose records will be supplied regularly and the controlling authority must keep them for two years (Reg 17(6)). It may also ask at any time for a copy of the dose record relating to a member of its staff or one of its students. The Health and Safety Executive* will receive from the approved laboratory annual summaries of the dose records, details of any person whose dose in a calendar quarter exceeds 0.03 Sv (3 rem) and, on request, a copy of a particular dose record.

4.1.7 In order that dose records may be reasonably complete, the controlling authority should, as soon as reasonably practicable after the regulations come into force, send to the approved laboratory suitable summaries of any dose records it holds relating to any of its staff or students who are, or may become, classified persons (ACl/115).

4.1.8 If a dosemeter issued to a classified person is lost or damaged the controlling authority must make an investigation with a view to estimating the dose received during the monitoring period. If there is enough information to estimate the dose it must ask the approved laboratory to enter this estimate in the dose record; if not it must ask for a notional dose, which is pro rata to the annual dose limit, to be entered (Reg 17(9)). The advice of the radiation protection adviser should be taken when making dose estimates.

4.1.9 The controlling authority must also make an investigation if it has reason to believe that the dose received by one of its staff or students is much greater or much less than shown in the dose record. If the investigation confirms this, it must apply to the Health and Safety Executive for approval of a special entry in the dose record (Reg 17(10)). The investigation should include:

(a) a survey of the person's work activities and of his exposure to ionising radiation during the period concerned,

(b) an estimate of the dose(s) likely to have been received,

(c) an explanation, with supporting evidence, for the supposedly wrong value in the dose record.

(ACl/117).

4.1.10 If more than one approved laboratory is concerned in the monitoring of a classified person, for example separate laboratories for external monitoring and internal monitoring (see 4.2.1), arrangements should be made for one of them to co-ordinate the measurements made by the others and maintain records of total doses received (ACI/112). Special arrangements will be necessary for overseas students or visiting staff who are also exposed to ionising radiation outside the United Kingdom; the approved laboratory in the United Kingdom should be able to maintain a record of the person's total dose while he is in the United Kingdom.

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*In Northern Ireland, the Department of Manpower Services.

4.1.11 If a member of its staff leaves and when a student finishes his course, the controlling authority must ask the approved laboratory to send a 'termination record' to the Health and Safety Executive* with a copy to itself. It may do this earlier if the person concerned ceases to be a classified person (Reg 17(4)).

4.1.12 The controlling authority must provide a student or member of its staff with a copy of:

(a) his dose record, on request or if it is amended (see 4.1.9),

(b) his termination record.

(Regs 17(7),(10),(11),(12)).

Dose information should also be available to the appointed doctor, the radiation protection adviser and the radiation protection supervisor.

4.1.13 Before designating a person as a classified person, the controlling authority should ask him about any previous work he has done involving ionising radiation and he should then provide any information he can about his previous dose (ACI/116). This information, which might be merely that the person had at some time been classified, should be passed to the approved laboratory. In the case of overseas students or visiting staff, a direct approach to the authorities in their home country may be necessary.

4.1.14 The radiation protection adviser may recommend that unclassified persons and visitors who enter controlled areas in accordance with local rules (see 2.6.4) should wear dosemeters. These dosemeters must be obtained from an approved laboratory and dose assessment reports issued by the laboratory must be kept for two years (Reg 17(5)). No dose records will be kept by the laboratory.

4.1.15 The controlling authority may also arrange for the wearing of dosemeters by persons who work in supervised areas or, if necessary, in non-designated areas, as a means of monitoring the working environment for external radiation or during particular procedures particularly when peaks of relatively higher exposure are expected. Monitoring need not necessarily be continuous; it may be sufficient to issue dosemeters for one or two periods during the year if doses are, pro rata, much less than three-tenths of the dose limits. There is no necessity to maintain personal dose records for such non-classified persons but the monitoring results should be kept as environmental records.

4.1.16 It is not usually practicable or necessary to monitor the dose to individual members of the public who visit, or pass near to, areas where ionising radiations are present (other than those who enter controlled areas). In order to ensure that the doses they receive are as low as reasonably achievable, and in any case less than the dose limits (see 1.4.1), the controlling authority should estimate, from data obtained by environmental monitoring, the dose that would be received by the most exposed individuals.

4.1.17 The controlling authority should draw up a personal dosimetry schedule which shows the names of persons whose doses are assessed, the types of dosemeters, the place on the body where they are worn, and the times and working areas in which they should be worn. The schedule should be available for inspection (ACI/118).

4.2 Personal monitoring for internal radiation

4.2.1 Classified persons who work with unsealed radioactive substances should also be systematically monitored for internal radiation unless sufficient measurements or estimates have been made to ensure that the committed dose due to intake will be less than one-tenth of the annual dose limit (ACI/108). Monitoring should be arranged with an approved laboratory and may take the form of:

(a) Monitoring of urine or faeces,

(b) Direct measurement of the radiations from the body using, for example, a whole body monitor or a chest monitor,

(c) Personal air monitoring.

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*In Northern Ireland, the Department of Manpower Services.

4.2.2 Monitoring details should be included in the personal dosimetry schedule. The persons concerned should provide the biological samples required and take reasonable precautions to safeguard them against contamination (ACl/110).

4.2.3 The intake of radionuclides in the monitoring period and in the year should be evaluated taking account of the circumstances of the intake when known (for example, chronic, single occurrence) and of intake in previous periods.

4.2.4 Monitoring of persons who are not classified persons is also valuable if intake is considered likely to be a significant fraction of the relevant ALIs and as a means of monitoring the working environment.

4.2.5 Advice about individual monitoring for internal radiation can be obtained from the Health and Safety Executive* or from the National Radiological Protection Board.† Guidance on the action to be taken in the event of intake of radioactive material in the body is given in H.P.A. Report Series No. 2.(121)

4.2.6 In addition to individual monitoring, where appropriate the levels of contamination of the skin, hair and clothing should be checked regularly to ensure that any excessive contamination is detected without delay (see 12.7.5).

4.3 Environmental monitoring

4.3.1 It is essential that any new or modified installation or laboratory is surveyed under the guidance of the radiation protection adviser in order to verify that the planned radiation protection is effective and the area designation is correct. Alternatively, the results of the survey may be used for deciding the designation of the area. It should be appreciated, however, that, particularly for work with unsealed radioactive substances, protection is as much a matter of procedure as of design. A modified installation/laboratory means one in which the original protection may no longer be adequate for any one of the following reasons:

(a) The radiation output of an X-ray or electron beam generator or a particle accelerator has been increased.

(b) The radiation output of a sealed source has been increased.

(c) The activity of an unsealed radioactive substance has been increased.

(d) The radionuclide used as an unsealed substance has been changed.

(e) The position of a radiation source has been changed.

(f) The techniques have been modified.

(g) The building has been modified.

4.3.2 A controlled or supervised area must be monitored in accordance with monitoring procedures which should be drawn up in consultation with the radiation protection adviser and specified in the local rules‡ (Reg 22(1) and ACl/154 and 155). This monitoring should determine:

(a) The levels of external radiation.

(b) The levels of radioactive contamination of surfaces in areas where unsealed radioactive substances are used and of the surfaces of personal protective equipment.

(c) The concentration of radioactive substances in the air if this is advised by the radiation protection adviser (see 12.7.7).

4.3.3 In addition to regular monitoring, a radiation survey should be made whenever personal monitoring results show that unusually high doses are being received. A survey is essential if individual monitoring indicates that the doses received exceed or are likely to exceed the dose limits, and if enquiries have failed to reveal the cause.

4.3.4 If a radiation survey indicates that any person is liable to receive a dose in excess of the dose limits, it is essential both to consult the radiation protection adviser about the measures to be adopted to remedy the situation and also to ensure that the installation is not used until the protection is satisfactory.

4.3.5 Environmental monitoring results must be recorded and kept for two years from the date of the last entry in the record (Reg 22(1)).

*In Northern Ireland, the Department of Manpower Services.

†In Northern Ireland, the Northern Ireland Radiation Protection Service.

‡See ACl/155 regarding the details of the monitoring procedures which are to be shown.

4.3.6 Other areas should also be surveyed periodically to ensure that they do not need to be designated and are not contaminated.

4.4 Environmental monitoring instruments

4.4.1 Suitable monitoring equipment must be provided (Reg 22(2)). It will include, as appropriate, dose rate meters, integrating dosemeters and contamination monitors. Instruments may be portable or used in a fixed position but those which operate alarms are unsuitable; so also are radiation detectors (see 6.7.11) unless they give a quantitative indication (AC1/157 and 158). Personal dosemeters may be used for fixed position environmental monitoring but, when worn on the body, they should be used only as a supplementary means of monitoring the working environment in controlled areas (see 4.1.15).

4.4.2 The suitability of a particular type of instrument should be judged on the basis of the manufacturer or supplier's specification, the assessment of performance of that type by a testing laboratory or by the radiation protection adviser, and the use to which the instrument will be put.

4.4.3 Commercial instruments, supplied specifically for environmental monitoring, should have undergone:

(a) a type test, and

(b) a pre-use test and calibration

in a test house approved by HSE* (†AC1/161 and 162). Other instruments should be given a pre-use test to a similar standard and should be calibrated before use (†AC1/163). Their use should be restricted to establishments under the control of the controlling authority or of the radiation protection adviser.

4.4.4 Instruments should be tested to ensure that the calibration is maintained in use, including a routine test of calibration at intervals not exceeding one year (AC1/164). Radioactive reference sources and contamination plaques (in non-dispersible form) should be available for making these tests. Radiation standards traceable to national standards should be used, where possible, for pre-use and routine tests (AC1/166).

4.4.5 After any repair which may have affected its calibration, an instrument should be given a routine test of calibration, or if necessary a pre-use test and calibration (AC1/165).

4.4.6 A record of maintenance and testing must be kept for two years after the last entry (Reg 22(4)).

5 General methods of reducing radiation dose

5.1 Introduction

5.1.1 This chapter describes the general methods of reducing the exposure of persons who work with, or come near to, radiation sources in order:

(a) to restrict their exposure to the minimum level reasonably practicable; that is to say, to keep doses as low as reasonably achievable, and

(b) to ensure that doses do not exceed the dose limits.

5.1.2 These general methods, which apply both to work with radioactive materials and with electrically generated radiation, may be considered under two headings:

(a) Reduction of dose from a source of ionising radiation outside the body (protection against external exposure).

(b) Reduction of dose and committed dose from radioactive materials which enter the body by inhalation, ingestion or other routes (protection against internal exposure).

The first applies to sealed and other closed sources, to machines which emit ionising radiation either intentionally or adventitiously and to dispersible radioactive substances; the second applies mainly to unsealed (dispersible) radioactive substances. It is convenient to include under the second heading the control of radioactive contamination which can give rise to both external and internal radiation hazards.

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*In Northern Ireland, the Department of Manpower Services.

†These requirements apply to all equipment supplied after [Two years after the regulations come into force] and after [five years afterwards] to all other eqiupment.

5.2 Protection against external exposure

5.2.1 The methods of reducing external exposure are:

(a) restriction of the strength of radiation sources,

(b) increasing the distance from the source(s),

(c) restriction of the time of exposure,

(d) shielding.

It will usually be necessary to employ a combination of measures failing under these headings.

5.2.2 Restriction of the strength of sources to the minimum consistent with the requirements of the work should always be the first precaution, except where more than a proportionate saving in time of exposure can be achieved by the use of more powerful sources.

5.2.3 A substantial reduction in radiation levels is achieved by increasing the distance, though the inverse square law applies strictly only to point sources. Use should be made of physical barriers which limit the closeness of approach and of remote handling tools for radioactive substances.

5.2.4 Restriction of the working time can also reduce the total dose received and may permit operations even in regions of relatively high dose rate. However, this method should not be the primary method of preventing doses from exceeding the dose limits. It should be assumed, for planning other protective measures, that a person will spend 40 hours a week at the most unfavourable position which is accessible to him, even if the radiation source is not normally used for as long as this. Although he could then spend his full working week there without exceeding the dose limits, restriction of the working time is still valuable in complying with the principle that doses should be as low as reasonably achievable. To reduce the time of exposure to the minimum, work should be carefully planned in advance. It may well be desirable to have trial runs using a dummy source or without exposing the source or energising the machine.

5.2.5 Shielding may be provided by materials already present, such as the walls of a room, or by materials specially selected and added. Materials of low atomic number should be chosen for shielding sources of ß-radiation in order to reduce the production of bremsstrahlung; the thickness used should exceed the range of the ß-radiation. Data on shielding for X- and γ-radiation are given in BS 4094.

5.2.6 As a general principle the shielding should be close to the source. Unless it is necessary to utilise the radiation coming from the source in all directions, the source should be surrounded by shielding which has, if necessary, an aperture for the egress of the radiation beam. The aperture in the source housing should limit the solid angle of the radiation beam so that the beam is no larger than is needed. Extended sources, such as ß plaques, should be backed by shielding material.

5.2.7 It is essential that no part of the body of any person is placed in the radiation beam or exposed to uncollimated primary radiation; equipment should incorporate safety features designed to prevent this automatically.

5.2.8 It will usually be necessary to provide primary shielding against the unwanted remainder of the radiation beam and/or primary radiation after it has passed the object being irradiated, image receptor and so on. This shielding should cover all areas to which the beam may be directed and should not take account of the attenuation by movable objects in the beam. Thinner, secondary shielding may be required in other directions to attenuate scattered radiation and leakage radiation from the source housing.

5.2.9 The best method of protection is to ensure than the equipment is shielded, and/or provided with barriers affording protection by distance, so that the dose rate outside the shielding or barrier is less than $7.5\,\mu$Sv h^{-1} (0.75 m rem h^{-1}), averaged over any one minute. The equipment could then be operated under the most unfavourable conditions for 40 hours per week and for 50 weeks per year without the dose to any person who is outside the barrier exceeding three-tenths of the dose limits for adult workers. Doses will usually be much lower than this and it is most improbable that the dose limits for members of the public will be reached. These are also administrative savings by achieving this level of shielding since it will not then be necessary to consider the need to designate surrounding areas as controlled areas on account of external radiation.

5.2.10 Shielding should be considered at the design stage to avoid costly, and possibly less than fully effective, changes afterwards. Attention should be given to joints between sections of the shielding which should be well-overlapped, gaps over and under doors, screws and bolts which may need capping and entry points for pipes and cables.

5.3 Protection against internal exposure

5.3.1 The methods of protection against internal exposure are:

(a) use of material of the minimum radiotoxicity where there is a choice;

(b) use of the minimum quantities;

(c) containment;

(d) use of protective clothing.

Guidance on these methods is given in Chapters 12 and 13.

6 Radiography, fluoroscopy and irradiation

6.1 Scope

6.1.1 This chapter of the guidance notes is concerned with the use of ionising radiations, in research and teaching, for radiography, fluoroscopy or for the irradiation of materials, animals or food. The purposes of irradiation include:

(a) the induction of chemical, physical or biological change in materials

(b) research into methods of such induction

(c) investigation of the extent to which materials are resistant to radiation damage

(d) sterilisation of materials

(e) preservation of food

(f) investigation of the effects of ionising radiation on animals.

The radiation sources considered include X-ray generators* operating at voltages up to a few hundred kilovolts and closed radioactive sources. The guidance also applies when the X-ray generator or radioactive source assembly, or the radiation measuring system, is being tested or calibrated in a way which requires the X-ray tube* to be energised or the useful beam of the radioactive source to be emitted.

6.1.1 This chapter does not apply to the examination of volunteers in approved medical and dental research projects or to the teaching of medical and dental radiography using human patients as subjects; these practices are covered by the medical and dental guidance notes.(123) Guidance on the radiography and fluoroscopy of animals is given in the veterinary guidance notes,(124) but will not necessarily be relevant to all types of examinations of animals in research.

6.1.3 The types of work covered by this chapter are amongst those to which Part 3 of the Approved Code of Practice applies. However the latter applies only:

(a) to machines operating at more than 5 kV;

(b) to 'sealed source equipment' (defined as one or more sealed sources or equipment containing one or more sealed sources) capable of giving a deep dose equivalent rate greater than 1 mSv h^{-1} (0.1 rem h^{-1}) at 1 m through air.

(AC3/2 and 3)

The approximate activities of some sources which give this dose equivalent rate at 1 m when unshielded are given in Table 6.1.

Table 6.1 Approximate activities of sources (unshielded) above which Part 3 of the Approved Code applies

Radiation	*Radionuclide*	*Activity (GBq)*	*Activity (mCi)*
γ	^{60}Co	2.9	78
γ	^{192}Ir	8	215
γ	^{137}Cs	11.6	315
γ	^{170}Tm	1570	42 500
β	^{90}Sr/^{90}Y	0.18	5
n	^{241}Am/Be	750	20 000
n	^{252}Cf	0.8	22 (0.04mg)

Part 3 of the Code will not usually apply to work employing low energy γ sources (<0.1 MeV), low energy β sources (<1 MeV) and neutron sources except ^{252}Cf.

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*In this chapter the terms 'X-ray generator' and 'X-ray tube' are used to include other types of machine which generate radiation (such as electron beam generators) except for particle accelerators which are considered in Chapter 10.

6.1.4 The potential hazard when carrying out radiography, fluoroscopy and irradiation will depend on factors such as the radiation output of the source, beam size and quality and the amount of scattered radiation. Particularly stringent precautions are required for the most powerful sources and the Approved Code therefore defines:

(a) 'high output machine' — capable of delivering a deep dose equivalent rate greater than 0.1 Sv/min (10 rem/min) at a distance of 1 metre in air, under conditions of use;

(b) 'high output sealed source equipment' — capable of delivering a deep dose equivalent rate greater than 0.01 Sv/min (1 rem/min) at a distance of 1 metre in air, under conditions of use.

(AC 3/3).

In the case of a machine which cannot give a continuous output, such as a flash X-ray tube, the dose equivalent rate should be averaged over one minute. Examples of radiation sources falling into the high output class are:

(a) beryllium window X-ray tube with little or no added filtration,

(b) 200 kV, 10 mA X-ray tube with filtration less than about 1.0 mm Cu.

'High output sealed source equipment' will be that having a source activity 600 times greater than that shown in Table 6.1. In practice, therefore, the only research equipment likely to fall into the high output class is that containing very large, high-energy γ sources. For convenience, sealed source equipment which is not in the high output class will be referred to as 'intermediate output equipment'.

6.1.5 Closed radioactive sources to which Part 3 of the Approved Code does not apply will be referred to as 'low output sources'. Part 1 of the Code continues to apply to their use. Advice on using them is also given in this chapter.

6.1.6 It is essential that the controlling authority identifies all machines and equipment in the high output classes and, separately, intermediate output equipment so that the provisions of Part 3 of the Code can be complied with. The necessary information may be obtained by direct measurement, by computation (such as from the activity where this is known), from the supplier or by consulting the radiation protection adviser. It may be possible to bring the source into a lower class without significantly reducing its effectiveness; for example, by increasing the permanent filtration in an X-ray beam and so removing non-effective soft components of the beam.

6.2 Construction of an enclosure

6.2.1 The process should, if reasonably practicable, be carried out inside a walled enclosure or cabinet so that it can be isolated from other work (AC3/6 and 7). A walled enclosure will be needed for examining or irradiating large objects and when substantial shielding is needed but, where it is feasible, a small cabinet should be used. This has the advantage that no-one can be accidentally shut inside (see 6.2.6). For work with low output sources, the use of an enclosure*, although not required by the Approved Code, should nevertheless be considered. It may avoid the creation, or limit the size, of a controlled or supervised area and help to restrict the extent to which the operator and other persons in the vicinity are exposed to ionising radiations.

6.2.2 The walls of the enclosure should provide shielding or distance protection so that there is no controlled area outside (AC3/8). To meet this requirement, it will usually be advisable to design the shielding so that the dose rate outside the enclosure is less than 7.5 μSv h^{-1} (0.75 mrem h^{-1}), (see 5.2.9). However, if the equipment is to be used intermittently, and particularly where the radiation source is incapable of continuous operation under the conditions needed for the work, it may be possible to allow a higher dose rate for limited periods leading to cost savings in the design. The advice of the radiation protection adviser or a radiation protection consultant should be obtained as they will be able to take into account factors such as the work load. Preferably, the space outside the enclosure should also not need to be a supervised area. If in some directions there is no working space (so that there cannot in any case be a controlled or supervised area) but the public has access, the same standard of shielding should be provided. Details of the properties of shielding materials and methods of designing shielding are given in British Standard 4094 (96) and ICRP Publication 21. (53) Care should be taken both when designing and when building shielding that there are no gaps through which either primary or scattered radiation could pass, for example under or around doors or at joints. However, since protection is required only in directions in which space is occupied, an open-topped enclosure with walls at least 2 m high may be acceptable. It should be ensured that scatter over the walls, including air scatter, is not excessive. The necessary degree of shielding should be provided for all likely beam directions and it may therefore be necessary or advisable to restrict the beam size and direction. A maze entrance should be considered for enclosures in which radiography or irradiation is to be carried out using powerful gamma sources. In the case of a neutron source it will be necessary to take account of both neutron and gamma radiation.

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*The word 'enclosure' will be used to mean either a walled enclosure or a cabinet.

6.2.3 The control point of an X-ray generator or of high output sealed source equipment should always be outside the enclosure. For intermediate output sealed source equipment the control point should be outside if reasonably practicable (AC3/14). It is essential that from no other position than at the control point is it possible to apply high voltage to the X-ray tube, to move the source or its shutters to the 'beam on' position, or to restore these conditions after interruption by a safety interlock.

6.2.4 The Approved Code calls for effective devices so that it is not possible to expose a useful beam while a door to an enclosure is open and which cause the exposure to cease if the door is opened (AC3/13). This requirement does not apply to intermediate output sealed source equipment with a control point inside the enclosure. 'Effective devices' include various types of electrical or mechanical interlocks such as:

(a) switch operated by the door as it opens or closes

(b) key which can be removed from the door only when the latter has been locked and which has to be inserted in the control cabinet before the electrical supply can be switched on.

A single device is sufficient so long as it can be considered reliable. It should be designed and positioned so that it cannot easily be tampered with and should be of a 'fail-safe' type. Exposure of a useful beam should not start with the mere act of closing the door but should be initiated from the control point (AC3/13), preferably after re-setting the door interlock by a positive action, in case the door closes accidentally. A 'door' should be understood to include a flap or cover over an opening to the enclosure, such as for introducing specimens. There is no specific requirement for a door, even at the main entrance to a walled enclosure, but a door will usually be needed to shield the opening and bar access while the examination or irradiation is in progress. If there is a maze entrance the door may be replaced by a light beam or bar so long as it forms an effective means of controlling access. The light beam or bar should be interlocked with the exposure controls.

6.2.5 If specimens are introduced on a moving belt the entry and exit ports should be designed so that no-one can insert his hands into a zone where the dose rate is high, that is, where the hands could receive more than three-tenths of the annual dose limit. The exposure should cease if the belt stops unintentionally, to allow manual removal of specimens.

6.2.6 Where necessary for the protection of persons who may be accidentally shut inside an enclosure, either

(a) the means of exit should be so positioned and constructed that those persons can leave the enclosure without delay; or

(b) means should be provided whereby those persons can quickly control all the sources of ionising radiation within the enclosure; or

(c) shielding appropriate to the circumstances should be provided for those persons within the enclosure.

(AC3/15).

If the first option is chosen it will be necessary to ensure that the door, even if locked, can be opened quickly from inside. The second option could consist of one or more switches conveniently placed inside the enclosure for interrupting the power supply to the X-ray tube or preventing the sealed source from leaving the fully shielded position. The third option could be the baffle wall of the maze entrance to a gamma irradiation facility. These precautions are unnecessary when a small cabinet is used, certainly if the internal volume is less than 0.2 m^3.

6.2.7 An enclosure which is large enough to be entered should be marked with a warning sign for ionising radiation (see Appendix 3), at least during the time that the enclosure is in use or ready for use.

6.3 Layout of a defined area

6.3.1 If it is not reasonably practicable to provide an enclosure the process should be carried out in a suitable area defined by barriers (AC3/7). The choice and size of the area will depend on the following considerations:

(a) No other work should be done in the area until the process has been completed (AC3/6);

(b) The space outside the barriers should not need to be a controlled area (AC3/8);

(c) It should be relatively simple to control access.

Barriers may be fixed or mobile. There are advantages in using existing walls as fixed barriers on one or more sides of the area; there can be no access through them except at doorways and they may provide shielding whereas mobile barriers normally offer only distance protection. Before the defined area is used, either it should be checked that the dose rate outside the barriers is less than 7.5 μSv h^{-1} (0.75 mrem h^{-1}) or the confirmation of the radiation protection adviser should be sought that the area outside is not a controlled area. Preferably, the barriers should be set so that the area outside is also not a supervised area.

6.3.2 The control point should be outside the defined area, if reasonably practicable, but always outside for X-ray generators and sealed source equipment in the high output classes (AC3/14). For X-ray generators the control point may be either the control panel or an exposure switch at the end of a cable. If the control point of an X-ray generator is inside the defined area the equipment should be arranged so that the X-ray beam will be directed away from the operator. The control point should be protected so that the radiation dose received there by a person not wearing protective clothing is not likely to exceed one-tenth of the dose limits. Unless the work load will be very low, the control point should be behind protetive panels and as far from the X-ray tube and object to be examined or irradiated as practicable. For voltages up to 100–150 kV, lead-ply panels provide valuable protection against scattered and leakage radiation. At higher voltages it is particularly necessary to arrange for the control point to be outside the defined area.

6.3.3 Work with low output sources does not come within these requirements for a defined area. However, if the work gives rise to a controlled area, barriers will be needed at the area boundary (see 2.4.8).

6.3.4 Warning signs for ionising radiation (see Appendix 3) should be displayed at all barriers past which people are liable to pass while the work is in progress.

6.4 Warning signals

6.4.1 The approved code requires effective visible or audible signals which will give adequate warning to everyone in the vicinity:

(a) when the X-ray tube is about to be energised or the beam from sealed source equipment is about to be 'exposed', and

(b) when the X-ray tube is energised or the beam 'exposed', the signals for the two conditions being readily distinguishable from each other.

(AC3/10)

The advance warning is not required if the total enclosed volume is less than 0.2 m^3 of free space. The number of warning signals needed will depend on the size and layout of the working space and whether an enclosure or a defined area is used. There should always be a 'Tube Energised/Beam On' signal at the control panel, for example, an amber light. In order to give a clear indication to the operator when an exposure is made the light should remain on long enough for the indication to be seen irrespective of the exposure duration. Further 'Beam On' signs should be provided outside entrances to enclosures and at a sufficient number of points on the perimeter of a defined area. These could be red lights or illuminated notices, preferably red, which say 'Do Not Enter', when the radiation beam is 'On' and which is not legible when the beam is 'Off'. An advance warning signal inside an enclosure or defined area should be designed to attract immediate attention, for example a flashing light or clearly audible sound. It should be given for a time which is sufficient for anyone accidentally shut inside the enclosure or still inside the area to take action. When a series of exposures is made without opening the door of the enclosure (or, in the case of a defined area, it is certain that no-one has entered between exposures) it is sufficient to give an advance warning only at the beginning of the series. The 'Beam On' signal should then be given throughout the series. Warning signals should be arranged so that if they fail the beam cannot be 'On'. For high output sealed source equipment it is recommended that there are additional lights at the control panel to show 'Beam Off' and 'In Transit'.

6.4.2 The meaning of all warning signals should be clearly explained on well-sited notices (AC3/12). A notice may be combined with a signal (illuminated notice) or be associated with a radiation warning sign (see 6.2.7/6.3.4).

6.4.3 Both the advance warning and the 'X-ray tube energised'/'Beam On' signals should operate automatically, always in the case of X-ray and high output sealed source equipment and where reasonably practicable for intermediate output sealed source equipment (AC3/11).

6.4.4 If X-ray equipment is provided with a shutter to control the exposure time and the X-ray tube remains energised when the shutter is closed, there should be additional signals at the control panel to indicate the shutter position, that is, 'Beam On' and 'Beam Off'.

6.5 X-ray equipment

5.5.1 X-ray tubes should be mounted in a protective housing. Except for those which are always used in an enclosure, leakage radiation from the housing should be as low as is reasonably practicable and in any case should not exceed 0.87 mGy (100 mR) in 1 h at 1 m from the focal spot at the maximum rated voltage and current and (in the case of tubes which cannot be operated continuously, such as flash X-ray tubes) pulse rate. Measurements may be averaged over an area of 100 cm^2.

6.5.2 Fluorescent screens should be viewed indirectly (AC3/20). The use of a directly-viewed fluoroscopic screen can be hazardous particularly if fluoroscopy is carried out in a defined area rather than in an enclosure. While it is acceptable to view the screen in an inclined mirror, the best method for fluoroscopy is to employ an X-ray image intensifier and a closed circuit television display.

6.6 Radioactive sources and their containers

6.6.1 All radioactive sources must be in the form of sealed sources unless it is not reasonably practicable to use a sealed source for a particular purpose (Reg 12). It is expected that it will nearly always be reasonably practicable to use radioactive material in the form of a sealed source for work covered by this chapter but if this is not so it is essential that a closed source is used. Although Part 3 of the Approved Code would not then apply it is essential that the standard of safety precautions is no less.

6.6.2 The immediate container or bonding of a sealed source should be of sound construction and adequate mechanical strength (AC1/202). Sealed sources should conform with British Standard 5288(102) where feasible and due regard should be taken of the supplier's recommendations on working life and environment of use.

6.6.3 Every source should have a means of identification (AC1/187) (see 14.7.1) and no source should be used without a valid leakage test certificate (AC1/204) (see 14.7.5).

6.6.4 The source should be housed in an exposure container in which it can be securely stored when not in use and which either has a shutter to allow the emission of a beam of radiation or permits the source to be moved into the operating position. If the work is to be carried out in a defined area the exposure container should be portable. Exposure containers for gamma radiography (other than the hand extraction type) should comply with British Standard 5650.(105)

6.6.5 When the source is in the storage position, leakage radiation from the exposure container, of any type and whether used for gamma radiography or not, should not exceed the values given in BS 5650. If leakage is in the form of beta radiation or neutrons it may be assumed that a dose equivalent rate of 10^{-2} mSv h^{-1} (1 mrem h^{-1}) in water is equivalent to 1 mR h^{-1}. This determines the maximum activity of that type of source for which the exposure container is suitable. The activity of the source should not exceed this value.

6.6.6 Every exposure container used in connection with radiography should comply with BS 5650 in its markings (AC3/21).

6.6.7 'All sealed sources should be moved using a handling tool or apparatus or some suitable method of remote control' (AC3/18). For low output sources there are similar requirements (AC1/138); radiography and irradiation sources should never be touched with the bare hands. A handling tool for moving a source from its storage position into the operating position, and *vice versa*, should be designed so that it can be firmly attached to the source holder and easily detached. A gamma source may need to be shielded while being held by a handling rod, for example, if a hand extraction type exposure container is used. Even with a shielded handling rod, the dose to a person transferring a gamma source exceeding about three times the activity shown in Table 6.1 becomes unacceptably high*. It is then essential to use remote means, such as a long cable or a pneumatic system with controls either outside the enclosure or defined area (see 6.2.3 and 6.3.2) or at a suitably large distance.

6.6.8 If the exposure container has a shutter its status should be clearly indicated (AC3/22). There should be an indication of the status, that is, 'Open' or 'Shut', at the exposure container as well as at the control point if there is remote control.

6.6.9 'Every exposure container should have a lock to prevent unintended or unauthorised exposure; the lock should be so arranged that if it becomes defective it will not prevent retraction of a source and the act of unlocking should not give rise to immediate exposure of a source' (AC3/23). These requirements will be met by an exposure container conforming with BS 5650 (except that the last point is not covered explicitly by the British Standard).

6.6.10 It is possible to make use of earth as a shielding material. The source could be kept in the secured position at the bottom of a lined well and raised to the working position; or the source could remain at the bottom of the well and objects to be irradiated could be lowered into the hole. The source should always be retrievable and there should be a cover over the irradiation well which is removed only for the short time needed to pass objects in and out.

6.6.11 When it is proposed to use radioactive sources which fall into the high output class the design of the plant requires very careful appraisal and specialist advice should be obtained, for example, from the radiation protection adviser, the National Radiological Protection Board or the Health and Safety Executive.†

6.7 Operating procedures

6.7.1 When a small cabinet is used it is necessary only to ensure that the warning lights and interlocks are working correctly and that the door is closed.

6.7.2 If a larger enclosure is used and the control point is outside, it is also necessary to check before starting the exposure that no-one has been accidentally shut inside. A search of the enclosure is called for by the Approved Code if the machine or equipment is a high output type (AC3/16).

6.7.3 If a defined area with the control point outside is used the area should be laid out as described in 6.3 and provided with sufficient warning signs and signals. All persons should be effectively excluded from the area while the process is being carried out (AC3/9) so barriers should be continuous and a check should be made before starting the exposure that no-one is inside. Special attention should be paid to places where someone might enter the area unobserved. The control point should be manned at all times while the exposure is in progress.

6.7.4 When a high output machine or a high output sealed source equipment is being used in a defined area the work should be done in accordance with the conditions specified in a certificate. This certificate should be drawn up by the controlling authority after consulting the radiation protection adviser and it should specify the working arrangements designed to give the same standard of protection as when using an enclosure (AC3/7). A copy of the certificate should be displayed at the control point.

6.7.5 If the control point is inside the enclosure or defined area it will be necessary for the operator to be inside for some or all of the time. He should be authorised to be there since access during the process should be limited to authorised persons (AC3/9 and 14). The procedure will differ according to the type of source:

(a) When a radioactive source is used the operator should be inside only to open the shutter or move the source to the operating position at the beginning of the examination or irradiation period and to return the source/shutter to the storage/closed position at the end. It is essential that he spends only the minimum time inside the enclosure or defined area. He should shut the door or close the barrier as soon as he is outside and ensure that no-one else enters. Security will be increased if the door can be locked.

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*The dose equivalent rate at 1 m from such a source would be 30 mSv h^{-1} (3 rem h^{-1}).

†In Northern Ireland, the Northern Ireland Radiation Protection Service or the Department of Manpower Services.

(b) When an X-ray tube is used (this will apply to a defined area only) the operator should remain in the protected area around the control point throughout the exposure.

6.7.6 An enclosure or defined area to which entry is authorised may need to be designated as a controlled area in which case the authorised person should be a classified person.

6.7.7 The approved code of practice calls for measures to keep the dose to an authorised person as low as reasonably practicable (AC3/9). Operational measures which will implement this are as follows:

(a) The equipment should be set up so that the radiation beam will be directed away from the control point, the entrance and the route between the two.

(b) The beam size should be checked on each occasion to ensure that it is no larger than is required. In radiography and fluoroscopy it should never be larger than the film or other image receptor.

(c) If an X-ray tube is used, the filtration of the beam should be equivalent to at least 2 mm of aluminium.

(d) Where a handling rod is needed for moving a radioactive source, the rod should be held so that the source is as far from the operator as practicable and directed away from him.

6.7.8 Authorisation should not be given for any person to be inside the enclosure or defined area during an exposure except in order to reach the control point. 'The examination/irradiation arrangements should be set up before any useful beam is exposed, and any changes in the arrangements required during the exposure should be made by remote means' (AC3/19). The radiation beam should not be directed at occupied areas unless they are adequately protected by shielding or distance (AC3/9).

6.7.9 It is strongly recommended that micro-radiography and other types of low voltage radiography are always carried out in a cabinet and not in a defined area. The dose rate in the virtually unfiltered beam from an X-ray tube with a beryllium window is very high and effective measures to prevent inadvertent exposure of the hands or other parts of the body are essential, both above and also below 5 kV.

6.7.10 The dose rate outside an enclosure or defined area should be checked regularly, and after changes in the radiation sources and the way they are used, to ensure that the shielding remains adequate and the barrier positions correctly placed. A portable radiation monitor should be available at all times if anyone is authorised to be in the enclosure or area during an exposure. It should be used to check that the authorised person is adequately protected and not exposed to high dose rates. Exposure containers should be checked regularly with their sources in the storage position and it should be ensured that the type and activity of the source is within the capacity of the container (see 6.6.5). The general advice in 4.4 on the selection, calibration and testing of monitoring instruments should be followed.

6.7.11 'The safe return of sealed sources to their containers by means of remote control after the completion of an exposure should always be verified by the appropriate use of a monitoring instrument' (AC3/17). If a projection type, or shutter type, exposure container is used it is essential that the authorised person, or the first person who re-enters the enclosure/area, checks that the source has returned to the storage position or the shutter has closed. It is unwise to rely on indicator lamps as the source might have become detached. Personal, audible dose rate monitors, preferably ones which are permanently switched on, should be worn by those who enter enclosures/areas in which high output sealed source equipment is used; they may be required by the certificate referred to in 6.7.4. So long as it is capable of giving a reliable indication, a radiation monitor used to show that it is safe to enter need not comply with 4.4.

6.7.12 It is essential that there is an emergency plan, known to everyone concerned, to be put into operation if a source has not returned to its fully shielded position or a shutter has not closed. These are foreseeable circumstances for which Reg 31 requires contingency arrangements to be made (see 2.9.1). Advice on emergency procedures is given in Chapter 16.

6.7.13 If there are two (or more) X-ray tubes in a defined area to which access is authorised, the greatest care is needed to ensure that the tube which is energised is the one which it is intended to use.

6.7.14 It is essential to lock exposure containers when the sources inside them are not in use. Keys should be kept secure at all times and should be made available only to those who are authorised to draw them (AC3/24). Portable containers should be placed in a secure store at the end of the work period (see Chapter 14). Where an exposure container is installed, access to the enclosure should be controlled at all times on account of leakage radiation.

6.7.15 Exposure containers and ancillary equipment shold be maintained in good working order and a maintenance record should be kept (AC3/25). It is particularly necessary to check that winding mechanisms on projection type exposure containers do not become stiff or cables frayed.

6.7.16 When a low output source is used, for example to investigate the effect on animals of radiation received at a low dose rate, the necessary precautions should be discussed with the radiation protection adviser or a consultant.

6.8 Loading and unloading sealed sources

6.8.1 From time to time it may be necessary to change a sealed source in an exposure container or other sealed source equipment. Unless it is a low output source, every endeavour should be made to carry out the process in conformity with paragraphs 6 to 25 of Part 3 of the Approved Code (as described in 6.2 – 6.7). However, it may be impracticable to comply fully; this is particularly likely if the equipment is in the high output class since those changing the source will probably need to be inside the enclosure or defined area whereas all persons have normally to be excluded. It will then be necessary to introduce a set of administrative controls and procedures to ensure that doses are kept as low as reasonably practicable and in any event below the dose limits (AC3/26).

6.8.2 The process should be carried out in accordance with a system of work drawn up by the controlling authority after consulting the radiation protection adviser and which is specified in a certificate; the work should be done only by persons named in the certificate and should be supervised (AC3/27).

6.8.3 It is essential that the persons named to carry out the loading and unloading are properly trained and experienced. The certificate should authorise them to be inside the enclosure or area.

6.8.4 The new source to be loaded should be brought into the enclosure or defined area in a shielded transfer container and the old source taken out in the same way.

6.8.5 When a high output source is changed particular care is needed to minimise the radiation dose to those taking part. The procedure may need to be rehearsed with a dummy source to ensure that it can be done sufficiently quickly yet surely. The radiation protection adviser may wish to be present so as to supervise the operation personally. Special dosemeters and dose rate meters should be used for monitoring the operation.

6.8.6 There should be a contingency plan, to be followed in case of difficulty. A contingency plan, well understood by those taking part, is essential when a high output source is changed.

6.8.7 After the transfer has been completed the equipment should be made suitable for normal operation. Any interlocks which may have been disconnected should be restored and this should be checked by the person supervising the operation.

6.8.8 If it is necessary to carry out a further leakage test on a sealed source, it should preferably be tested without removing it from its exposure container (see 14.7.5 and 14.7.6).

6.8.9 Simplified procedures may be used when changing low output sources but it is essential that suitable handling tools are used.

6.9 Irradiation of food

6.9.1 No food which is intended for sale for human consumption may receive a dose of more than 50 rad and the energy of the radiation must not in any case exceed 5 MeV (The Food (Control of Irradiation) Regulations 1967, as amended in 1972).(38, 39) 'Food' includes drink and milk products but not water or milk. There are special arrangements for food to be consumed by patients requiring a sterile diet.

7 X-ray crystallography and spectrometry

7.1 Scope

7.1.1 This chapter covers the use, maintenance and testing of all types of X-ray diffraction and spectrometric equipment incorporating an X-ray tube.

7.1.2 A section of Part 4 of the approved code of practice applies to this work.

[A special guidance note, giving more detailed information, is being prepared on this subject.]

7.2 Hazard

7.1.2 The X-ray tubes used in this type of equipment are designed to produce high intensity, narrow beams of X-radiation into which specimens are inserted. The dose rate in a primary beam may be as high as tens of grays (thousands of rads) per second and accidental exposure of any part of the body for only a few seconds can therefore result in an acute radiation burn. The annual dose limit to the skin of the face or hands would be received almost instantaneously in an uncollimated beam near the target.

7.2.2 Although some X-ray tubes have only one beam aperture, others have up to four. Open apertures, with no accessory in place over them, are the principal hazard to the operator and to other people in the vicinity.

7.2.3 There are lesser hazards from diffracted beams, mainly to the hands of the operator, and from stray radiation if equipment is insufficiently protected or if accessories are not correctly fitted.

7.2.4 With regard to the first note to Table 1.1, it is recommended that doses to the skin from intense beams of X-radiation should be averaged over an area of 1 cm^2 when applying the dose limit. This is in line with paragraph 183 of ICRP Publication 26. It is recognised that beams will frequently have a cross-sectional area of less than 1 cm^2 but it is not considered either appropriate or necessary to specify an averaging area less than this.

7.3 Equipment

7.3.1 All radiation beams produced by the equipment should be fully enclosed and access by parts of the body, such as the hands or eyes, to any X-ray beam within the equipment should be prevented by the provision of shielding, barriers and special safety features (AC4/5). This is the preferred method of keeping doses to laboratory workers and others as low as reasonably practicable and in any event below the dose limits.

7.3.2 The equipment should preferably be shielded so that it can be operated continuously throughout working hours without the dose to any person exceeding three-tenths of the dose limits for adult workers (see 5.2.9). The deep dose equivalent rate outside the equipment should not exceed 7.5 Sv h^{-1} (0.75 mrem h^{-1}) and the shallow dose equivalent rate, averaged over 1 cm^2, should not exceed 75 μSv h^{-1} (7.5 mrem h^{-1}). Crystallographic equipment usually consists of an X-ray tube in a housing with 1 to 4 apertures and one or more cameras or other attachments. It will be necessary to ensure that:

(a) leakage radiation from the X-ray tube housing is less than 7.5 μSv h^{-1} (0.75 mrem h^{-1}).

(b) all cameras and accessories are enclosed (preventing access to the collimated and diffracted beams) and have adequate beam stops, and

(c) connections between different parts of the system are 'radiation-tight'.

Alternatively, the whole apparatus apart from the control panel and ancillary equipment, should be completely enclosed in a shielded box or cabinet (see 7.3.7). Spectrometric equipment is usually easier to shield but the loading port(s) need special attention (see 7.3.12).

7.3.3 A shutter or cover should be provided at every aperture through which a primary beam could emerge into the laboratory or irradiate the hands. For a crystallographic X-ray tube, any aperture which is not in use should be closed by a cover which cannot be removed without the aid of tools. An aperture which is used should have a shutter which closes when the camera or other accessory is removed. This safety shutter should be additional to the electro-mechanical shutter used to control the primary beam. Closed shutters and covers should provide the same standard of shielding as the rest of the apparatus.

7.3.4 Special safety features are needed to ensure that the equipment cannot be operated in an unsafe manner. An effective device or devices should close the shutter or cover, or switch off the high voltage from the X-ray tube:

(a) if any accessory is removed from an X-ray tube port, or

(b) if all or any part of the surrounding structure (see 7.3.7), which prevents access to a radiation beam is removed or opened

(AC 4/8).

With regard to (a), the device could be a mechanical arrangement which locks the accessory in place while the shutter is open but which allows it to be taken off when the shutter is closed. It should not be possible to open the shutter without an accessory, designed for use with the X-ray tube, in place. Another method is to arrange for the accessory to open the shutter automatically, for example by fitting a probe which depresses a microswitch on the tube housing when the accessory is in its correct position close to the aperture. A spring would cause the shutter to close if the accessory is removed. Covers and access panels in the surrounding structure should be interlocked with the high voltage supply or with an electrically operated beam shutter. This requirement of the Approved Code applies only where accessories, covers etc are readily removable. There are also potential hazards if accessories are partially dismantled, collimators detached from monochromators etc. It will not usually be practicable to provide interlocks for all such openings and connections and other methods are needed (see 7.3.7). The extent to which parts need to be detachable or opened will clearly depend on the type of work being done but should be restricted to what is necessary.

7.3.5 For the safety devices to be effective they should:

(a) function continuously, irrespective of whether the equipment is being aligned or adjusted, or in normal use,

(b) be reliable, and

(c) be reasonably proof against improper or unauthorised interference.

A device which opens the shutter automatically should be designed so that it is not possible for the primary beam to be 'On' with more than a small gap between the X-ray tube and the accessory under any conditions of use. Particular care is required when the angle of the accessory relative to the beam axis is changed. The gap should be covered by overlapping parts which form a radiation labyrinth and the interlock switch should operate before the labyrinth separates. A spring which closes a shutter should be sufficiently strong in case the shutter tends to stick open after a period of use. For the same reason, a gravity-operated shutter cannot be considered effective, though it is preferable that the shutter is closed in its lowest position. Safety devices should be designed to be 'fail-safe'.

7.3.6 When failure of a safety device could rapidly result in an overdose two reliable independent systems should be provided.

7.3.7 Where integral parts of the equipment do not afford effective barriers, the equipment should be totally or partially enclosed or a distance barrier, such as a light beam interlocked with the X-ray tube voltage, provided (AC4/7). Complete enclosure of the equipment is recommended where cameras need to be opened, collimators changed, and so on and there is no effective way of ensuring that the fingers cannot enter a radiation beam. This method is particularly suitable for older equipment which does not possess all the recommended safety features and which it is not reasonably practicable to modify. Its disadvantages are:

(a) It is difficult to make adjustments while the beam is 'On'. If it is necessary to align the equipment with panels open and interlocks by-passed, part of the advantage is lost.

(b) It is difficult to arrange for the independent use of a number of cameras on one X-ray tube.

7.3.8 There should be means to indicate to any person in the immediate vicinity:

(a) when an X-ray tube is energised (automatic indication),

(b) whether any shutter is open or closed whilst an X-ray tube is energised (automatic indication when reasonably practicable) (AC4/9).

(AC4/9).

The X-rays 'On' signal should preferably take the form of an illuminated sign indicating 'X-rays On' on two or more of its sides; this sign should not be legible when unlit. For maximum reliability either 2 lamps should be wired in parallel or the circuit should be arranged so that if the lamp fails the shutter closes or the high voltage supply to the X-ray tube is immediately interrupted. The shutter position may be shown by indicator lamps or by a prominent mechanical system and 'closed' should be indicated only when the shutter is fully closed.

7.3.9 The 'X-rays On' and shutter position indicators should be sited at eye level on or near to the equipment and, where relevant, to the aperture to which they relate and not only on the control panel.

7.3.10 It should not be possible to apply high voltage to the X-ray tube, or restore the supply after it has been interrupted by a safety interlock, except from the control panel. The switch should be clearly marked.

7.3.11 If it is necessary to override an interlock on an access panel, it should either be necessary to use a key which is available only to authorised users, or there should be a device which will automatically restore the interlock to its effective state. Interlocks should be overridden only for the purposes of alignment or adjustment.

7.3.12 If an X-ray spectrometer has a fixed position sample well it is essential that the well is provided with a cover which;

(a) is interlocked with the beam shutter,

(b) provides sufficient shielding.

When there is a separate loading position it should be ensured that under no circumstances can the fingers be irradiated.

7.3.13 Advice about the methods of modifying equipment which does not meet these requirements or recommendations may be obtained from the Health and Safety Executive or from the National Radiological Protection Board.*

7.4 Administrative arrangements

7.4.1 It may be wished to continue using equipment which does not comply with all the requirements of the approved code relating to shielding, barriers and effective devices given in AC4/5-8 and referred to above. The radiation protection adviser should be consulted in order to assess the potential hazard of doing so and the risk of an overexposure (AC4/22). It should be noted that the indications required by AC4/9 (see 7.3.8) are always required. There may also be occasions, in particular when aligning a beam or making other adjustments, when it is necessary to override a safety feature so the radiation protection adviser should be similarly consulted.

7.4.2 If foreseeable exposure might result in an overexposure, departure from the preferred arrangements already described should not be considered unless they are impracticable. Instead there should be a system of work which ensures that the dose limitation objectives are met (AC4/20). This system of work should be drawn up by the controlling authority after consulting the radiation protection adviser and should be specified in a certificate. The work should be done only by persons named in the certificate and under supervision (AC4/21).

7.4.3 However, if it is considered that an overexposure is most unlikely, the work may be done but the local rules should include the radiation protection adviser's recommendations on procedure (AC4/22). Warning notices and possibly increased supervision should reflect any relaxation in the provision and use of protection features.

7.4.4 It is recommended that equipment in university and college laboratories which is used by undergraduates should conform fully with the requirements of the approved code without recourse to special administrative arrangements.

7.5 Operating procedures

7.5.1 Users should be thoroughly familiar with the equipment and with its safety features. They should be given instructions regarding normal operation and, when appropriate, beam alignment and/or have ready access to the manufacturer's operating manual regarding the latter.

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*In Northern Ireland, the Department of Manpower Services or the Northern Ireland Radiation Protection Service.

7.5.2 When a number of separate items have to be combined the user should ensure that the assembly is complete, with all necessary shielding in position, before switching on the X-ray tube or opening the shutters.

7.5.3 So far as reasonably practicable, adjustments, such as change of filter, should be made with the X-ray tube switched off. The greatest care should be taken if the collimation needs to be adjusted by eye when the X-ray tube is 'On' so that in no case is the eye directly exposed to the beam.

7.5.4 When it is necessary to align or adjust crystallographic equipment with the X-ray beam 'On' and for this purpose an enclosure cover or access panel has to be removed, it is essential to take the strictest precautions to minimise the dose from scattered radiation and diffracted beams and to avoid absolutely exposure to the primary beam. Such precautions include:

(a) reducing the X-ray tube voltage and current to the lowest practicable values for carrying out the alignment or adjustment;

(b) using any practicable mechanical aids which will allow the hands to be further from radiation beams or scattering points;

(c) making the adjustments in a reasonably short time;

(d) minimising the frequency with which adjustments of this type have to be made.

Further:

(e) It is likely that the procedure described in 7.4.2 will be necessary but in any case such adjustments should be made only by persons specially authorised by the controlling authority or head of department.

(f) The radiation dose to the hands of the persons concerned should be monitored.

(g) After completing the adjustment it is essential that the cover or access panel is replaced and that any interlock which it has been necessary to override is restored to its effective state.

7.5.5 If adjustments to analysing crystals of X-ray spectrometers are necessary, similar precautions should be taken. Temporary shielding should be used where appropriate.

7.5.6 During maintenance or alteration of the system the X-ray tube should be completely isolated from the supply mains by physical disconnection, such as by the removal of a plug. It may be necessary to arrange that other equipment can continue to operate.

7.5.7 A prominent warning notice should be attached to equipment which has to be left partially dismantled and/or in an unsafe working condition.

7.5.8 When more than one person or team makes independent use of a multi-window X-ray tube it is essential that the work is co-ordinated. There are particular hazards where all uncovered apertures do not have automatic, fail-safe shutters. One person should be nominated to supervise and co-ordinate the use of the apparatus.

7.5.9 Tongs will normally be used for loading and unloading samples into X-ray spectrometers. The fingers should not be inserted into sample wells since they might be exposed to stray radiation in the 'Off' position.

7.5.10 Portable spectrometers should be used only in conjunction with a shielded sample drawer. They should not be used in a mode which requires them to be held against the specimen.

7.6 Monitoring

7.6.1 Crystallographic and spectrometric equipment should be monitored frequently because small adjustments can substantially increase the level of scattered radiation. Monitoring is essential after re-alignment, modification and servicing.

7.6.2 Radiation surveys should be made with instruments capable of detecting very narrow beams of scattered radiation supplemented, for positions where access is difficult, for example, sample wells, by film or thermoluminescent detectors.

7.6.3 Since accurate dosimetry of narrow beams of low energy scattered radiation is difficult, the aim should be to eliminate leakage as far as practicable rather than to measure it. Comparatively simple radiation detectors may therefore be suitable so long as it is possible to recognise if shielding is insufficient.

7.6.4 It should be recognised that there is only a low probability that a personal dosemeter worn on the trunk will detect a narrow beam of radiation to which the person might be exposed. The wearing of a personal dosemeter could engender a false sense of security and so should only be a supplement to frequent area monitoring.

8 Measurement and detection devices and miscellaneous research

8.1 Introduction

8.1.1 This chapter gives guidance on the use of ionising radiations in thickness, density and level gauges, soil moisture meters and other types of analytical, inspection or gauging equipment and also in detection devices, such as smoke detectors, and static eliminators. Both closed sources and electrically generated radiation are considered.

8.1.2 A section of Part 4 of the Approved Code of Practice contains requirements for this work including testing of the equipment and the loading and unloading of radioactive sources.

8.1.3 Where a gauge is used for diagnostic measurements on human beings, the Medical and Dental Guiance Notes (123) should be followed.

8.1.4 The guidance in this chapter should be followed, when relevant, for all other work not covered by other chapters, for example, research into the properties of radiations.

8.2 General requirements

8.2.1 The equipment should be enclosed and shielded in order to keep doses as low as reasonably practicable and in any case below the dose limits with particular regard to the radiation beams which are needed for some types of work (AC4/4, 10 and 11).

8.2.2 Effective barriers should be provided to prevent insertion of any part of the body into a radiation beam or into a region inside the equipment where this might lead to an overexposure (AC4/12). The barrier may be a solid structure totally or partially enclosing the equipment, a guard or fence which provides distance protection, or a beam of light interruption of which operates an interlock (see 8.3.2).

8.3 The use of X-ray or electron beams

8.3.1 The general requirements can most easily be met if the radiation source, specimen and measuring head are totally enclosed, for example, in a cabinet. The enclosure should preferably be shielded so that the dose rate outside it is always less than 7.5 μSv h^{-1} (0.75 mrem h^{-1}). This will avoid the need to consider the setting up of a controlled area (see 5.2.9).

8.3.2 'Where part of a machine can readily be moved to allow emergence of or access to a beam or field of radiation that might lead to overexposure, effective devices should be provided which automatically de-energise the machine or which close some shutter (or coverplate or shield) so as to shield the beam of ionising radiation' (AC4/13). All doors or panels which have to be opened in order to introduce specimens into an X-ray beam should therefore be interlocked with the high voltage supply or with a beam shutter. Interlocks should be of a fail-safe type.

8.3.3 For electron beam devices the vacuum chamber may be completely effective in preventing insertion of any part of the body into the useful beam. If the electron beam emerges from the vacuum chamber its range in air is usually short. However, there may well be intense fluorescence X-radiation which is either essential or incidental to the functioning of the equipment and against which protection is required.

8.3.4 The enclosure may have entry and exit ports, such as, for specimens in continuous strip form or carried in and out on a moving belt or for fluids or pneumatic transfer systems, through a pipe. The ports should either be small enough to prevent the insertion of the operator's hands or there should be sufficiently long entrance and exit tunnels.

8.3.5 Where a transmission gauge is to be used for measuring a stationary or moving strip which cannot easily be totally enclosed, the radiation source and the measuring head should be mounted opposite and as close to each other as possible so that there is only a small gap for the strip to pass through, too narrow for insertion of the fingers. Guards on either side will often be needed to prevent the hands from entering a region where scattered radiation would give a high dose rate. The measuring head should fully intercept the remainder of the beam.

8.3.6 In the case of a back scatter gauge, the dose rate of transmitted radiation could be high if the sample is relatively thin. There should always be an effective beam stop.

8.3.7 The safety of all equipment should be assessed both with and without specimens in the beam. Fluorescent and scattered radiation sometimes vary markedly according to the material.

8.3.8 There should be clear indications of when the radiation source is about to be energised and when it is energised (AC4/14). The advance warning signal is particularly necessary when the equipment is not totally enclosed; it is intended to ensure that anyone close to the gauge has time to withdraw his body and hands from an area close to the beam where there might be a high dose rate of scattered radiation. Where the radiation beam is controlled by opening and closing a shutter, there should also be clear indications of when the shutter is about to be opened and when it is open (AC4/14). All the warning signals should be distinguishable from each other and they should operate automatically (AC4/14). Warning signals may be visual or audible. If the former is chosen the warning signal can conveniently be a flashing light to distinguish it from a steady light which indicates the operating condition. The meaning of the various signals should be clearly explained on accompanying notices unless the indications are self-explanatory, for example, an illuminated notice only legible when the radiation beam is 'On'. Warning signals should 'fail to safety', that is to say it should not be possible to energise the radiation source if the signals fail.

8.3.9 Full details of the way in which it is proposed to use the equipment or experimental arrangement, including particulars of the X-ray tube or electron gun voltages and currents, beam sizes and directions, should be given in advance to the radiation protection adviser so that he may take account of them in his assessment and radiation surveys.

8.3.10 The equipment should be operated only in the mode for which the radiation protection adviser or the radiation protection supervisor has given his approval.

8.3.11 Whenever equipment is altered, modified or moved in such a way that shielding is or may be reduced, it should be re-monitored before further use.

8.3.12 If equipment has to be left partially dismantled and/or in an unsafe working condition there should be a means to prevent access or operation. If this is not reasonably practicable, a prominent warning notice should be attached to the equipment.

8.4 The use of closed sources

8.4.1 Sources must, wherever reasonably practicable, be sealed sources (Reg 27). To ensure that the requirements of AC1/202 regarding the immediate container or bonding are complied with, sealed sources should conform with British Standard 5288 (102) and due regard should be taken of the supplier's recommendations on working life and environment of use.

8.4.2 It is essential that all sources used in gauging and analytical equipment are, and remain, closed sources. Any necessary modification of the immediate container or bonding of a source should be carried out only by a person authorised in writing by the controlling authority and in accordance with specific instructions laid down after consultation with the radiation protection adviser (AC1/209).

8.4.3 One can recognise three types of equipment:

(a) The source is enclosed in the apparatus in such a way that there is no direct access to it (for example, in a dew-point meter, gas chromatograph, smoke detector or static eliminator).

(b) The source is mounted in a housing which has an aperture for the radiation beam (for example, thickness gauge, fluorescence analyser).

(c) The source is projected out of its housing when in use (for example, soil moisture meter).

8.4.4 Equipment of the first type may or may not require additional shielding depending on the type of radiation source and its activity. For the other types the source housing should be well shielded. (See 5.2.5 and 5.2.6.)

8.4.5 At each aperture there should be a shutter or coverplate which can be easily closed or fitted when the radiation beam is not in use or the source has been retracted into the housing. In the closed position the shutter or cover should provide as much shielding as the rest of the housing. Preferably the shutter should be spring-biassed so that it can be open only when material which is to be measured is in position. Effective visible or audible signals should indicate whether the shutter, coverplate or shield is open or shut (AC4/15).

8.4.6 The best method of avoiding exposure to a radiation beam is to fully enclose the equipment (see 8.4.3(a) and 8.3.4). Fluorescence analysers are available into which samples are introduced via a shielded drawer; the drawer has to be closed before the sample reaches the measuring position. Where the equipment is not fully enclosed the advice in 8.3.5 and 8.3.6 should be followed.

8.4.7 The equipment should be clearly and durably marked to indicate that it contains radioactive material (AC4/15). The marking should include the radiation symbol (see Appendix 3).

8.4.8 The way in which the equipment is to be installed and used should be agreed with the radiation protection adviser and/or the radiation protection supervisor.

8.4.9 If a shutter or cover does not operate automatically (see 8.4.5) it is essential that it is closed or replaced as quickly as possible after the measurement. Particular care is required in the use of portable gauges.

8.4.10 The source probe in a soil moisture meter should remain in its fully shielded position within the instrument until the latter has been placed over an access hole in the ground.

8.4.11 Portable instruments containing radioactive sources should be placed in a secure store at the end of the work period (see Chapter 14). Installed equipment should be made secure. If the leakage radiation gives rise to a dose rate exceeding 7.5 μSv h^{-1} (0.75 mrem h^{-1}) access to the room should be controlled at all times. It may sometimes be feasible to detach the source housing and move it to a store, but only if there are special provisions for protecting the operator should the source(s) be removed.

8.4.12 No source which could otherwise give rise to a dose rate to the skin (averaged between the depths of 5 and 10 mg cm^{-2}) exceeding 0. 1 μSv h^{-1} (10 mrem h^{-1}) should be manipulated with the bare hands (AC1/138). If it is necessary to remove or replace a source, it should be gripped with forceps or preferably a specially designed handling tool and transferred to and from a shielded source container.

8.4.13 The equipment should be used only with a source of the type and activity advised by the supplier or approved by the radiation protection adviser.

8.4.14 Every source should have a means of identification (AC1/187) (see 14.7.1) and no source should be used without a valid leakage test certificate (AC1/204) (see 14.7.5).

8.5 Administrative arrangements

8.5.1 The approved code prefers the provisions of AC4/10-12 (referred to in 8.2.1, 8.2.2 and 8.3.2) to be followed in order to achieve the general objectives of:

(a) keeping doses as low as reasonable and in any case below the dose limits, and

(b) preventing exposure to radiation beams leading to the receipt of significant doses to parts of the body.

It does, however, permit the alternative arrangements which are described in 8.5.2–8.5.4. The difficulty in complying fully with AC4/10–12 is recognised in some of the guidance given in 8.2, 8.3 and 8.4.

8.5.2 The radiation protection adviser should be consulted in order to assess the potential hazard of operating equipment which does not fully conform with AC4/10–12 and the risk of an overexposure (AC4/22).

8.5.3 If an overexposure is most unlikely (which is probable with most kinds of laboratory gauges and analytical equipment) the work may be done but the local rules should include the radiation protection adviser's recommendations on procedure (AC4/22). Warning notices and possibly increased supervision should reflect any relaxation in the provision and use of protection features.

8.5.4 Occasionally, foreseeable exposure might result in an overexposure. Departure from the preferred arrangements should not be considered unless they are impracticable; instead there should be a system of work which ensures that the objectives are met (AC4/20). This system of work should be drawn up by the controlling authority after consulting the radiation protection adviser and should be specified in a certificate. The work should be done only by persons named in the certificate and under supervision (AC4/21).

9 Incidental radiation

9.1 Scope

9.1.1 This chapter is concerned with X-radiation that is generated adventitiously and unintentionally by high voltage equipment. Other types of unwanted radiation, such as neutrons generated by electron accelerators or radiation produced when material in the vicinity of accelerators is unintentionally rendered radioactive, are considered in Chapter 10.

9.2 Hazards

9.2.1 Every piece of equipment containing any part or component which is evacuated or in which there is a gas discharge, and which is operated above 5 kV, should be considered as a potential source of adventitious X-radiation. Such sources will therefore include:

Electron beam welding apparatus

Electron microscopes

Radar and microwave transmitters incorporating, for example, klystrons or magnetrons

Cathode ray tubes in television receivers, monitors and visual display terminals

High voltage gas-filled tubes such as rectifiers and thyratrons.

This list should not be considered as exhaustive.

9.2.2 The hazard will depend on the voltage and current and on the form and materials of construction. Some or all of the X-radiation may be absorbed in the walls of the vacuum tube or chamber which, in order to withstand atmospheric pressure, sometimes have to be comparatively thick or dense. For example, it is unlikely that X-radiation will be emitted by a cathode ray tube with an applied accelerating voltage of less than about 20 kV. However, for small devices and especially for those that have thin windows, the voltage above which measurable radiation is emitted is often much lower than this. Above the voltage threshold, the radiation emitted increases rapidly with increasing voltage, and it will normally be proportional to the current.

9.2.3 The X-radiation is frequently confined to particular parts of the equipment and emitted in certain directions only. If the device is continuously pumped radiation may be emitted through the pump stem. Its intensity may depend on the degree of vacuum.

9.2.4 There is unlikely to be a hazard from unwanted electrons. Though electrons might be emitted by a device with an exceptionally thin window they would be absorbed in surrounding air or, harmlessly, in outer layers of the skin unless the accelerating voltage is considerably above 100 kV. At higher voltages, measures to shield the equipment against adventitious X-radiation will also be effective against electrons.

9.3 Approved code of practice

9.3.1 One section of Part 4 of the Approved Code applies to the use or testing, at its place of use, of any device in which charged particles are accelerated by a voltage of more than 5 kV and which generates ionising radiation incidentally.

9.3.2 All the requirements of the Approved Code, except possibly external marking will be met automatically by:

(a) apparatus incorporating a cathode ray tube intended for the display of visual images if the supplier can show that the dose rate at 5 cm from any accessible surface does not exceed 5 μSv h^{-1} (0.5 mrem h^{-1}), and

(b) apparatus which is of a type approved by the Health and Safety Executive and from which the dose rate at 10 cm from any accessible surface does not exceed 1 μSv h^{-1} (0.1 mrem h^{-1}).

The first category includes television receivers conforming with BS 415: 1979 (89) and visual display terminals. The British Standard states that the maximum exposure rate applies not only under normal conditions but also under fault conditions when any controls on the equipment, whether accessible to the user or not, allow an intelligible display to be restored. Operation of apparatus in the first category is not notifiable work (Schedule 5 to the Ionising Radiations Regulations).

9.4 Precautionary measures

9.4.1 No administrative measures, such as registration of work (see 2.9.1), or regular radiation monitoring are needed for equipment coming within either of the two categories of 9.3.2.

9.4.2 Where reasonably practicable the equipment should be shielded so that it does not give rise to a controlled area (AC4/16). This requirement will be met most easily if it can be shown that the dose rate outside the equipment never exceeds 7.5 μSv h^{-1} (0.75 mrem h^{-1}) averaged over any one minute. A radiation survey should be made when the equipment is installed or set up, and should be repeated periodically or when some significant change has occurred (see 4.2). If the dose rate exceeds 7.5 μSv h^{-1} for short periods the shielding will still be sufficient if the radiation protection adviser is satisifed on other grounds that the area outside the equipment does not need to be designated as a controlled area.

9.4.3 It is essential that the radiation survey is made while the equipment is being operated under the most unfavourable conditions which are used in practice. For example, electron microscopes should be checked with the beam magnets both focused and de-focused; electron beam welders should be operated with a block of tungsten in the beam to simulate maximum scattering. The equipment should be operated at the maximum voltage during the survey but may also need to be checked at a lower voltage if the current is then greater. All modes of operation should be considered.

9.4.4 If, as is preferable, radiation protection has been correctly assessed at the planning stage (see 5.2.10), the radiation survey will confirm that the shielding is appropriate. If this is not so additional shielding should be fitted, or distance protection increased, and the survey repeated. Up to at least 50 kV, sheet steel (rather than aluminium) and sufficiently thick glass (rather than perspex) for observation windows will usually afford effective shielding. Lead, preferably in the form of lead ply, and lead glass will be needed only for equipment which operates at higher voltages.

9.4.5 It is essential that the monitoring instruments used to determine that shielding is sufficient are suitable, bearing in mind the following points:

(a) adventitious radiation is often emitted in narrow beams;

(b) the energy of the radiation may be low;

(c) some equipment, for example klystrons or magnetrons, may be operated in a pulsed mode. It will then be necessary to integrate the radiation over one minute and to ensure that the detector does not saturate at very high instantaneous dose rates;

(d) high frequency may be present and this could affect instrument readings.

9.4.6 Occasionally it will not be reasonably practicable to provide the required shielding. This might be because an experimental set-up is to be used only for a short time. (However, a temporary, portable barrier could still be useful.) It will then be necessary to designate the area around the equipment as a controlled area. The equipment giving rise to the controlled area should be clearly identified and labelled as such and clear indication should be automatically given at the boundary of the controlled area. The operator would then need to be a classified person or covered by a 'scheme of work' (see 2.4.11). The indication at the boundary could be a red light with an explanatory notice, or an illuminated notice, which comes on when the high voltage is applied. There should also be an indication of the 'On' state, preferably an amber light, at the control panel. It is preferable, sometimes essential, to site the control panel outside the controlled area or as far from the equipment as practicable.

9.4.7 It will sometimes be necessary to gain access to the inside of the equipment by opening a door or panel. If the dose rate inside the equipment is such that persons working there, or who insert their hands, might otherwise receive an overexposure, effective devices should be provided which will terminate the radiation when any access panel or door is opened (AC4/17). This requirement depends on the possibility rather than the probability of an overexposure and action should be taken if the dose rate inside the equipment exceeds 25 μSv h^{-1} (2.5 mrem h^{-1}) or, if only the hands can be exposed, 250 μSv h^{-1} (25 mrem h^{-1}). An electrical interlock should therefore be fitted to any panel or door which can be opened (for example, to give access to a testing compartment) without the use of tools. This will not be necessary in the case of electron beam welders which can be operated only under a vacuum and therefore not when a loading port is open.

9.4.8 The approved code, while preferring the method described in 9.4.7, permits an alternative approach when the hazard from radiation inside the equipment is low, that is, when an overexposure is most unlikely. The radiation protection adviser should be consulted in order to assess the potential radiation hazard and the risk of an overexposure. His recommendations on procedure should be incorporated in the local rules (AC4/22). These rules might, for example, allow experimental high voltage equipment of a specified class to be operated for a limited time with panels removed, with or without the use of tools, subject to certain safeguards such as the wearing of dosemeters. As a minimum there should be clear warning notices (see 9.4.9) and adequate supervision of the work. For some types of high voltage equipment used in research, such as high power klystrons, the possibility of an overexposure if the equipment is operated without all of its shielding in place cannot be dismissed as 'most unlikely'. Departure from the arrangements described in 9.4.7 should not be considered unless they are impracticable. Instead, there should be a system of work which ensures that doses are as low as reasonably practicable and in any case below the dose limits (AC4/20). This system of work should be drawn up by the controlling authority after consulting the radiation protection adviser and should be specified in a certificate. The work should be done only by persons named in the certificate and under supervision (AC4/21).

9.4.9 Equipment which generates radiation incidentally should be identified and labelled or marked externally with a warning sign for ionising radiation (AC4/18) (see Appendix 3). It should, however, not be necessary to mark equipment referred to in 9.3.2. The warning sign should indicate that the equipment is properly shielded as 9.4.2 (except where the conditions described in 9.4.6 apply) and that the removal of any panels or casing may impair the protection. The local rules should require that:

(a) the equipment is operated only in an agreed manner, and

(b) the radiation protection supervisor is informed of any change in location or surroundings of the equipment, if it is damaged or modified or if there is any other reason to think that the emission of ionising radiation has increased.

These instructions may be repeated as part of the warning sign. If protection has been impaired, a warning notice should be displayed to prevent the equipment from being operated until it has been repaired and rechecked. Where access is possible to the inside of the equipment, individual sources of ionising radiation should be clearly and separately marked with a warning sign (AC4/18).

10 Particle accelerators

10.1 Scope

10.1.1 This chapter describes the principal precautions which are necessary for the installation and use,* other than in medical research involving the irradiation of human subjects, of particle accelerators. These include such machines as linear accelerators, neutron generators, Van de Graaff electrostatic generators, cyclotrons, betatrons, synchro-cyclotrons, synchrotrons and proton synchrotrons.

10.1.2 Part 3 of the approved code which covers non-medical radiography, fluoroscopy and irradiation is relevant to the use* of particle accelerators, other than in medical practice. Its requirements are considered in the following sections. Some of these requirements apply only if the equipment is capable of giving a deep dose equivalent rate greater than 0.1 Sv min^{-1} (10 rem min^{-1}) at 1 metre. Most accelerators will fall into this class.

10.2 General

10.2.1 As these machines give rise to very specialised and difficult safety problems, it is essential that the controlling authority has available staff competent to assess the hazards involved and advise on the protective measures to be taken.

10.3 Equipment and installation

10.3.1 An accelerator should be installed inside a walled enclosure† where it can be isolated from other work (AC3/6 and 7). The walls of the enclosure should provide shielding so that there is no controlled area outside (AC3/8). This may be achieved by designing the shielding so that the dose rate outside the enclosure does not under any conditions exceed 7.5 μSv h^{-1} (0.75 mrem h^{-1}) averaged over any one minute. If this dose rate may occasionally be exceeded, the radiation protection adviser should be asked to confirm that, nevertheless, there will be no controlled area outside the enclosure. He will take into account all relevant operational factors and may wish to specify in writing limiting conditions for the use of the accelerator. Preferably, the space outside the enclosure should also not need to be a supervised area. There are advantages in siting the accelerator in a single-storey building.

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*Including testing and calibration.

†See also 10.4.10.

10.3.2 The required shielding will depend on the nature and direction not only of the primary beam, but also of the scattered and secondary radiations. The target is not the only source; the beam usually strikes other objects. In a positive ion accelerator secondary electrons travel in the reverse direction and strike the chamber walls and electrodes. Neutrons may be produced adventitiously by machines of energy exceeding about 8 MeV and consequently may form a significant fraction of the stray radiation from very high energy equipment. Prompt gamma radiation is produced in shielding materials by the scattering and absorption of ions or neutrons. It is necessary to take account of the quality factor of the radiation, which is greater than 1 for neutrons, protons and other heavy particles. The quality factors, and factors for converting neutron and proton fluence rate to dose equivalent rate, given in Annex II of Directive 80/836/Euratom (82) (which are taken from ICRP data), should be used. Concrete, possibly loaded with material of higher atomic number, is one of the most valuable shielding materials for accelerators, but other materials may be more suitable for particular parts of the installation. The design of shielding requires specialised knowledge and advice may be obtained from an external advisory service such as the National Radiological Protection Board'.*

10.3.3 Shielding design should allow sufficient space around the machine for the modifications of research programmes, the maintenance of electronic equipment, the detection of vacuum leakage and the installation of targets.

10.3.4 The control panel should be outside the enclosure (AC3/14) and, in order to exclude persons during periods of operation, the doors of the enclosure should be interlocked effectively with the accelerator (AC3/13). The interlocks should be arranged so that the primary beam is immediately switched off if any door of the enclosure is opened, and cannot be switched on until the door has been closed and the interlock reset. Exposure should not start at the mere act of closing the door but only after the primary beam has been switched on at the control panel (AC3/13). It should not be possible to switch on the beam at any other place. There should be either a reset switch outside the door or, if the door can be closed only by a positive action, this action may be used to reset the interlock (see 10.4.2 regarding the search interlock).

10.3.5 The enclosure should be marked with a warning sign for ionising radiation (see Appendix 3).

10.3.6 The approved code requires the provision of:

(a) advance warning, by means of effective and automatically operated visible or audible signals, that the accelerator is about to be energised, and

(b) continuous warning that the accelerator is operating by means of automatically operated visible or audible signals which are readily distinguishable from those under (a). (AC3/10 and 11).

There should be one of each of these warning signals at the entrance, either in the form of lights, preferably amber for the advance warning and red for the 'beam on' conditions, or of illuminated notices. These notices would indicate the two conditions and should not be legible at other times. There should be further visible signals at the control panel. It is essential that signals are also given inside the enclosure to warn anyone who may be inside. The advance warning could take the form of a flashing light or an intermittent audible signal or both, the 'beam on' condition being indicated by continuous signals. Warning signals should be arranged so that if they fail the beam cannot be 'On'.

10.3.7 The meaning of all warning signals should be clearly explained on well-sited notices (AC3/12). A notice may be combined with a signal in the form of an illuminated notice or be associated with a radiation warning sign (see 10.3.5).

10.3.8 For the protection of persons who may be accidentally shut inside an enclosure, the approved code requires:

(a) means of exit, so positioned and constructed that those persons can leave the enclosure without delay, or,

(b) means whereby those persons can quickly control all the sources of ionising radiations within the enclosure, or,

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*In Northern Ireland, the Northern Ireland Radiation Protection Service.

(c) shielding appropriate to the circumstances for those persons within the enclosure. (AC3/15).

These options are qualified by the words 'where necessary', but, in the case of particle accelerators, such arrangements will nearly always be necessary because stray radiation levels are likely to be high. Option (b), which refers only to generated radiation in the case of an accelerator, may be met by the provision of one or more switches within the enclosure, arranged so that the operation of any switch interrupts all high voltage supplies and prevents their restoration from the control panel. Option (c) might be satisfied by the baffle wall of a maze entrance.

10.3.9 The possibility that the accelerator might be switched on while someone is accidentally shut inside can be greatly reduced by the use of a switch key. The equipment is designed so that the key has to be inserted in the control panel and turned before it is possible to apply any high voltage to the accelerator. The same key is used to unlock the door before anyone can enter the enclosure and to reset the door interlock when everyone has left (see also 10.4.2).

10.3.10 It should be borne in mind that radiation may be generated or present in the 'beam off' condition. For example, small 'dark currents' of electrons may be inadvertently accelerated when the machine voltage or radio-frequency generating system is turned on, even if the ion or electron source is not turned on. With certain types of accelerator it will be necessary to take precautions against radiations which continue to be radiated after the machine has been switched off, for example, by discharging the capacitance of a direct accelerator or by stopping the charging belt of a Van de Graaff generator. When neutrons have been generated the apparatus and surroundings may be radioactive. It is essential to take these points into consideration when designing door interlocks, warning signals and emergency switches inside the enclosure.

10.3.11 The particle beam accepted by the main accelerator system may be formed and pre-accelerated in a separate apparatus. Shielding, door interlocks, warning signals and emergency switches will then need to be effective for the injector system as well as for the main accelerator.

10.3.12 It is essential to assess at the planning stage the hazards which may arise due to radioactivity induced in surrounding materials, including air and dust. Shielding materials should be chosen with this in mind and effective ventilation should be provided by means of a mechanical exhaust system which discharges into the open air at a suitable height, after filtration if necessary.

10.3.13 Where a continuously pumped neutron generator tube is installed, the exhaust from the pumping system, which will contain tritium gas released from the target, should be discharged outside the building.

10.3.14 Particle accelerators may present electrical, mechanical and chemical hazards (for example, from ozone and oxides of nitrogen) and special risks of fire and explosion (for example, which may arise in the cooling system forming part of the high vacuum equipment).

10.3.15 A beam of accelerated particles may be passed along a beam tube through an aperture in the wall of the enclosure into a second enclosure. It is essential that this second enclosure meets all the requirements for the first enclosure which are appropriate.

10.4 Operating procedures and maintenance

10.4.1 It is essential that particle accelerators are operated only by persons with sufficient knowledge of the equipment and of its potential hazards. Staff should be given suitable training before they are allowed to operate the accelerator. Responsibility for safe operation should, at any given time, lie with a single individual.

10.4.2 No one may be inside the enclosure during periods of operation (AC3/9). Dose rates can be very high, an electron beam being particularly dangerous. Electrons are easily scattered and the hazard is not confined to the primary beam. To ensure that no one has been accidentally shut inside a search should be made before the beam is switched on (AC3/16). This search is necessary on each occasion when the door has been opened between exposures and, to verify that it has been carried out, it is recommended that there should be a push-button switch inside the enclosure which has to be operated by the searcher before it is possible to reset the door interlock. There should preferably be an interval of not more than say, half a minute between the two operations. If the control panel has a switch key (see 10.3.9) this key should be carried by a person who enters the enclosure. Where an emergency switch is provided inside the enclosure (see 10.3.8 (b)) a person working inside the enclosure should turn off this switch (if necessary, locking it in the 'Off' position by means of a key or padlock) so that the beam cannot be switched on at the control panel while he is inside.

10.4.3 It is essential to monitor neighbouring areas that might be occupied during the operation of particle accelerators in order to confirm that shielding is appropriate (see 10.3.1 and 10.3.2). The monitoring instruments should be suitable for the type(s) of radiation liable to be present, and the survey should be made sufficiently carefully so that any unexpected distribution of radiation is detected. The radiation may sometimes be sharply pulsed, for example when a klystron is installed.

10.4.4 Adequate and suitable monitoring instruments should be available at all times to persons who use particle accelerators. If the machine is intended to produce heavy particles or neutrons, persons entering the enclosure should use these instruments to recognise any induced radioactivity. They should also do so when using light particle accelerators above 8 MeV. Monitoring is particularly necessary before any work is done in the vicinity of the beam path, target or the magnet system. If significant activity is detected, protective measures, such as remote handling and the wearing of protective clothing, should be taken or, where practicable, further work postponed until short-lived activity has decayed. Unwanted items contaminated with long-lived activity should be disposed of as radioactive waste (see Chapter 15). Precautions against radiation and contamination will always need to be considered if the accelerator is used for the production of radionuclides or for activation analysis.

10.4.5 Special types of personal dosemeters may need to be worn (see 4.1.2).

10.4.6 If significant activity is likely to be induced in air or dust, the enclosure should not be entered immediately after switching off the primary beam to allow the exhaust system to reduce this activity (see 10.3.12). The advice of the radiation protection adviser should be sought on the need for air monitoring or the wearing of respirators where the hazard is liable to persist.

10.4.7 Tritium targets for neutron generators, and any other radioactive materials which are used for targets, should be handled only with tools. Some of the tritium released from the target will be trapped in the vacuum system so precautions appropriate to the handling of unsealed radioactive materials should be taken in changing the pump oil or carrying out other pump maintenance. Old pump oil should be treated as radioactive waste (see 15.2.5(i)). Contamination of the accelerator system may be even more widespread if tritium is used as an accelerated particle (see 12.7.6 regarding contamination monitoring for tritium).

10.4.8 Accelerators should be used only under locally agreed operating conditions which are described in the local rules. In many circumstances, small changes in these conditions may produce disproportionately large changes in radiation hazard from external radiation and from induced radioactivity; there may be changes in the nature as well as in the intensity of the radiation. The radiation protection adviser should be informed of proposals to change the operating conditions.

10.4.9 If it is wished to mount additional experimental devices inside the enclosure, care should be taken not to impair the shielding. If it is necessary to remove any shielding or over-ride any interlocks during maintenance, it is essential that the radiation protection supervisor is satisfied that safe working conditions hve been fully restored before the accelerator is again operated.

10.4.10 Very occasionally, it may not be reasonably practicable to install the accelerator in a walled enclosure, for example if it is used for radiography of large or fast-moving objects. The work should then be carried out in a suitable area defined by barriers (AC3/7). Except for door interlocks, the arrangements already described for the use of an enclosure should be followed:

(a) No controlled area outside the barriers

(b) The control panel to be outside

(c) All persons to be excluded from the area during the process

(d) Warning signals and signs to be provided (AC3/8–12 and 14).

The work should be done in accordance with the conditions specified in a certificate drawn up by the controlling authority after consulting a radiation protection adviser. This certificate, a copy of which should be displayed at the control point, should specify the working arrangements designed to give the same standard of protection as when using an enclosure (AC3/7).

11 Research reactors

11.1 The detailed precautions necessary in the use of a nuclear reactor for research or in carrying out critical or sub-critical experiments are outside the scope of these guidance notes, though the general measures described are applicable. The Ionising Radiations Regulations apply in addition to other legislation.

11.2 The conditions specified in the nuclear site licence (see 2.2.12) must be adhered to.

11.3 Precautions must be taken against hazards due to accidental super-criticality caused by maloperation of the reactor or by an increase of reactivity due to interaction of the core with an experimental assembly (Reg 32). Guidance is given in British Standard 3598(93).

11.4 While a properly designed reactor shield will provide adequate protection against gamma radiation and neutrons from the core, there may be appreciable hazards associated with experimental assemblies. Local monitoring is therefore essential and additional shielding may be required.

11.5 Materials exposed to neutrons in or from the reactor will become radioactive. It is essential that all samples and equipment removed from the reactor are monitored for direct radiation and for contamination and that arrangements are made for suitable handling and protection.

11.6 Where necessary personal monitoring should include the wearing of neutron dosemeters in addition to those sensitive to beta and gamma radiation.

11.7 Contingency arrangements will be necessary (see 2.10). They should include the issue of suitable dosemeters obtained from an approved laboratory to persons who are likely to receive the highest doses in an incident (AC1/224). The dosemeters should be of a specialised type for nuclear accident dosimetry.

12 Work with unsealed radioactive substances

12.1 Scope

12.1.1 This chapter contains guidance on the precautions required for work with unsealed radioactive substances other than those which, though not sealed, are classed as closed sources. When unsealed radioactive substances are used in medical research either for administration to human subjects or for *in vitro* tests made for the purpose of clinical study, the medical and dental guidance notes should be followed. Some additional precautions where radioactive substances are administered to animals are considered in Chapter 13.

12.1.2 There is no specific part of the approved code of practice on this work but reference is made to paragraphs in Part 1 of the code which are particularly relevant.

12.2 Hazards from unsealed radioactive substances and principles for their control

12.2.1 A radiation hazard may arise from unsealed radioactive substances either through external irradiation of the body, or through the entry of radioactive substances into the body. The main precautions required in dealing with external irradiation are similar for both sealed sources and unsealed substances and depend essentially on the physical characteristics of the radiation emitted and on the physical half-life of the radionuclide. In addition, unsealed radioactive substances may produce a further external radiation hazard as a result of contamination.

12.2.2 When unsealed radioactive substances enter the body, the radiation dose will depend also on factors such as the physical and chemical form of the material, the mode of entry and the way in which it is metabolished. A radionuclide may be dispersed in the body, concentrated in a particular organ, or eliminated more or less quickly. However, radioactive material within the body represents a greater hazard than the same activity as an external source. α-emitting radionuclides pose the greatest internal hazard but α-radiation outside the body is unable to penetrate the skin.

12.2.3 The International Commission on Radiological Protection (ICRP) has published values of 'annual limits on intake' (ALI) for workers (61) (see 1.2.6 and Appendix 1). Ingestion and inhalation are considered separately and, for some radionuclides, more than one value of ALI for each is given corresponding to different chemical forms of the material. Knowledge of the ALIs may be used as a basis for controlling hazards from unsealed radiation substances. They should, however, be considered as upper limits only in view of the requirement that all doses – and consequently intakes of radioactive material – are as low as reasonably practicable (see 1.1.3). ALIs do not include any radioactive substance administered to a worker for medical purposes.

12.2.4 Further limits which are useful for controlling hazards may be derived from the ALIs, such as:

- Derived air concentrations (see 12.5.6)
- Limits for biological monitoring, for example the activity of a particular radionuclide in the urine (see 4.2.1).

Limits for surface contamination (see Appendix 4) depend partly on ALIs and partly on the doses from external radiation.

12.2.5 The International Atomic Energy Agency has derived a classification of radionuclides according to relative radiotoxicity (79) to which further radionuclides used in this country have been added by the National Radiological Protection Board. This classification, which also takes account of the specific activity, is shown in Schedule 2 to the Ionising Radiations Regulations. It indicates the comparative hazard involved in work with various radionuclides; however, it should be noted that the classification may require modification for radionuclides incorporated in complex chemical compounds. The precautions to be taken regarding internal hazard will therefore depend on the radiotoxicity class, the physical and chemical form and the nature of the procedure as well as the total activity.

12.3 Design of laboratories

12.3.1 It is essential that unsealed radioactive substances are manipulated only in working areas recognised, equipped and reserved for this work except:

(a) When work, such as a tracer experiment, has to be done outside the establishment;

(b) For very low level work.

In both cases the agreement of the radiation protection adviser should be obtained.

12.3.2 The design of all laboratories in which unsealed radioactive substances are used, the design of all equipment required in their use, and the procedures involved in work with such substances should be aimed at:

(a) Minimising the irradiation of persons in the course of their work or training;

(b) Controlling the spread of radioactive substances into the working environment.

12.3.3 The radiation protection adviser should be consulted about the design of laboratories (AC1/82). Changes that may become necessary from time to time should also be discussed with him. Precautions regarding fire or other emergencies need to be considered at the design stage (see 2.10).

12.3.4 Where work involves the use of widely different levels of activity, separate rooms are preferred. Counting apparatus should normally be situated in a separate room. A suite of rooms should be designed so that radioactive materials can be moved from one room to another, where necessary, without passing through surrounding areas.

12.3.5 Laboratories may be graded for design purposes into three types according to the maximum activities to be handled at any time and the radiotoxicity of the nuclides concerned (Table 12.1). This grading is also useful in deciding whether an existing laboratory is suitable for carrying out new procedures, either involving different nuclides or higher levels of activity than are currently in use.

The activities shown in Table 12.2 should be multiplied by the operational factors shown in Table 12.2. In some cases a range is given because the factor will depend on local circumstances and variation in complexity of one and the same type of procedure. The advice of the radiation protection adviser should be sought on the operational factors to be used so that the activity limit or range for each area or operation can be established. For example it might be agreed that up to 500 MBq (14 mCi) of iodine-131 could be stored in a grade 3 area. If more than one radionuclide is to be stored it is necessary to determine the weighted sum of the individual activities.

Table 12.1 Grading of working areas

Radionuclide	*Grade 3*	*Grade 2*	*Grade 1*
α emitters	<5 kBq (140 nCi)	5 - 500 kBq (140 nCi - 14 µCi)	>500 kBq (14µCi)
^{90}Sr	< 500 kBq (14µCi)	500 kBq - 50 MBq) (14 Ci - 1.4 mCi)	>50 MBq (1.4 mCi)
^{44}Ti, ^{60}Co, ^{106}Ru ^{110}mAg, ^{109}Cd, ^{115}mCd, ^{114}mIn, ^{125}I, ^{131}I, ^{144}Ce	< 5 MBq (140µCi)	5 -500 MBq (140 Ci - 14mCi)	>500 MBq (14 mCi)
Th-nat U-nat U-dep U-env	<50 MBq (1.4 mCi)	50 MBq - 5 GBq (1.4 - 140 mCi)	>5 GBq (140 mCi)
*^{99}mTc	<1 GBq (27 mCi)	1 - 100 GBq (27 mCi - 2.7 Ci)	>100 GBq (2.7 Ci)
^{3}H	<5 GBq (140 mCi)	5 - 500 GBq (140 mCi - 14 Ci)	>500 GBq (14 Ci)
Others	<50 MBq (1.4 mCi)	50 MBq - 5 GBq (1.4 - 140 mCi)	>5 GBq (140 mCi)

*The values of activity given for ^{99}mTc apply only in areas where no parent ^{99}Mo is present.

Table 12.2 Operational factors

Type of area or operation	*Factor*
Storage*	100
Radioisotope laboratory	1–0.1
Administration to animals	1–0.1
Animal houses	1
Counting room	100–10
Storage of active waste and for radioactive decay	100–1

*Includes the parent activity in a radionuclide generator (the daughter need not be considered) but not the eluate.

12.3.6 Before a laboratory or other area where unsealed radioactive substances are to be used or stored is brought into use, it will be necessary to consider if it needs to be designated as a controlled or supervised area on the grounds of external radiation or the hazards of intake of radioactive material by workers (see 2.4.4). It is unlikely that a grade 3 area will need to be so designated. A grade 1 area will probably be a controlled area but no general prediction can be given for a grade 2 area; it will depend upon the recommendations of the radiation protection adviser.

12.3.7 All areas which are liable to become contaminated, and all fittings and equipment in them, must, so far as is reasonably practicable, be designed and constructed so as to minimise this contamination and permit decontamination (Reg 21(1)). This applies particularly to controlled and supervised (intake hazard) areas (ACI/145) and refers to both surface and airborne contamination. Since the eventual designation of the area may not be known when it is designed, it is recommended that the particular requirements for controlled and supervised areas described in the following sections should be incorporated in the design of all grade 1 and grade 2 areas.

12.3.8 The floor, walls, ceiling, benches, tables and seats in controlled or supervised (intake hazard) areas should have smooth, impervious surfaces which can be easily cleaned (ACI/146). The materials used should be chosen with regard to their resistance to corrosion by chemicals, heat and fire. Floor coverings should be 'non-slip' and should (after welding if necessary) be in one continuous sheet. The standard of finish in a modern conventional chemical laboratory is adequate for a grade 3 laboratory.

12.3.9 The design of the laboratory or area should eliminate, as far as possible, ledges and inaccessible places liable to collect dust. Only essential fittings and equipment, which can easily be cleaned and decontaminated, should be installed in controlled and supervised (intake hazard) areas (ACI/146 and 147).

12.3.10 It is essential that the floor and benches, including worktops inside enclosures, are strong enough to support the weight of any necessary shielding materials or of radionuclide generators. A wall of lead bricks 50 mm thick weighs 570 kg m^{-2}.

12.3.11 Levels of airborne contamination should be kept as low as reasonably practicable by the use of total or partial ventilated enclosures (see 12.3.13(b) or by local or general ventilation of the area (AC1/134). Good ventilation with local exhaust[*] should be provided in grade 1 areas; forced ventilation may be needed in grade 2 areas. The system should be designed so that air does not pass into surrounding working areas. Normal general ventilation is sufficient for grade 3 areas.

12.3.12 One or more wash-hand basins, fitted with foot, knee or elbow operated taps[†] and with hot and cold water supply, should be provided. There should be one such basin for every five persons close to the exit of every controlled or supervised (intake hazard) area next to the changing facilities referred to in 12.3.13 (c) (AC1/150 and 151).

12.3.13 A radioisotope laboratory should have the following additional special features:

(a) Adequate storage space so that essential equipment used in the laboratory is kept there, thus minimising the risk of spreading contamination to other areas.

(b) For grade 1 or grade 2 laboratories, one or more fume cupboards or glove boxes, whichever is appropriate, designed for ease of decontamination (see 12.4.1 and 12.4.5).

(c) An entry lobby, or an area near the entrance, where protective clothing (see 12.5.2) can be put on, taken off and kept when not in use. The Approved Code requires changing facilities for all controlled and supervised (intake hazard) areas to prevent contamination from being transferred outside the area. There should be[‡] a bench or other demarcating barrier at the exit, places for clean clothing to be left outside the barrier and for protective clothing and equipment on the 'active' side, and containers on the 'active' side for discarded contaminated clothing (AC1/148 and 149). If α-emitters are to be used it is essential that grade laboratories are completely separated from the surrounding area by a bench barrier where overshoes are put on or footwear changed.

(d) A secure and adequately protected local store for radioactive substances (see 14.3.1)

(e) Adequately protected temporary storage for solid radioactive waste (AC1/152 in the case of controlled and supervised (intake hazard) areas). Disposable plastic sacks of distinctive colours are convenient for this purpose, and they should be suitably marked.

(f) A limited number of places, designated and clearly marked for the disposal of radioactive liquid waste. Where direct disposal of low activity waste to drains is authorised the drain should be connected as directly as possible to the main sewer and, in the case of grade 1 areas, capable of taking a high water flow. Any traps should be accessible for monitoring.

(g) Depending on the type and activity of radionuclide to be handled, shielding in order to protect the worker from unnecessary exposure to external radiation (AC1/132). Persons in adjacent rooms or corridors will need to be protected from gamma-radiation which may penetrate the floor, walls or ceiling.

(h) A wash-up area for contaminated articles such as glassware. The drain and traps should comply with (f) above. This area may be combined with (f) or with the hand-washing facilities in grade 3 laboratories. Subject to the approval of the radiation protection adviser, it may be combined with (f) in grade 2 laboratories but not with hand-washing.

12.3.14 Since no dispensing or preparation of samples will normally be carried out in areas set aside for sample measurements, the structural requirements of such areas are governed chiefly by the equipment to be used. However, since a high standard of radioactive cleanliness is required and there is some risk of spills, the floor, walls and benches should be finished with smooth, non-absorbent surfaces which can be easily cleaned.

12.3.15 In order to be able to carry out any decontamination of persons which may be necessary, an area should be designated for this purpose if there is a grade 1 or grade 2 area. It should be equipped to carry out procedures referred to in sections 12.8.3 – 12.8.5.

12.3.16 If an area is designated a controlled or supervised area warning signs will have to be posted (see 2.4.8). However, it is recommended that all working areas where unsealed radioactive substances are present should be marked with a sign indicating ionising radiation (see Appendix 3).

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[*] Or continuous movement of air into a fume cupboard.

[†] Remotely operated taps are required in controlled areas only.

[‡] For controlled areas and, where necessary, also for supervised areas.

12.4 Enclosures and extract systems

12.4.1 It is essential that fume cupboards have an efficient mechanical exhaust draught system to prevent the spread of contamination into the working area. The air flow through a working aperture 0.3 m high (or the maximum aperture if less than this) should therefore be at least 0.5 linear m s^{-1} over the whole aperture. Turbulent airflow should be avoided by aerodynamic design. The exhaust system may need to continue functioning when work is not in progress unless it is ensured that, with the exhaust switched off and the window fully closed, significant quantities of radioactive material cannot escape from the enclosure. A laboratory provided with a fume cupboard is normally ventilated by continuous movement of air into the cupboard. Care should be taken to see that the ventilation is adequate if the exhaust is switched off (see 12.3.11). Details of the design of fume cupboards are given in British Standard 3202.(90) Fume cupboards should not be sited next to a door or window because of cross draughts unless it can be shown that containment is adequate.

12.4.2 Extracts from enclosures and from ventilation systems should be 'filtered where necessary and vented to an appropriate place in the open air' (AC1/135). The exhaust from laminar flow cabinets and fume cupboards should be separated from the normal ventilation system and should be discharged through ducting not in close proximity to windows and air intakes and at an adequate height. Ideally the height should be 1½ times the height of the building but a discharge point 2 or 3 m above the roof is usually sufficient. Provided that each outlet point is well selected, filters will usually be unnecessary but their use might be advised by the radiation protection adviser for some high activity work. The extractor fan should be positioned close to the outlet in order to maintain a negative pressure throughout the duct and the motor should be outside the duct.

12.4.3 Smoke tests are a useful aid in investigating an installation to verify that the exhaust system will be adequate in adverse circumstances (for example, when windows and doors are open and the wind conditions are unfavourable) and that it will prevent radioactive dust and vapours escaping from the enclosure directly into the working area or into the air of neighbouring rooms through the external vent.

12.4.4 Consideration should be given to the possibility of having to decontaminate the exhaust ducting if long-lived radioactive substances (such as those with a radioactive half-life greater than 100 days) are used in the enclosure. The ducting should be made of non-absorbent, fire-resistant material and capable of being removed in sections.

12.4.5 A glove box fitted with an exhaust fan and ducting to the outside of the building, and operated under slightly reduced pressure, can afford a useful alternative to a fume cupboard and may avoid the need to classify the operator. It also has the advantage of requiring a very small air flow and thus does not disturb significantly the existing provision for heating the department. Moreover, it is often possible to convey the exhaust air more conveniently to the outside without disturbing the building structure. A glove box should be used in preference to a fume cupboard for operations involving α-emitters, when this is practicable. The equipment should be capable of continuous operation.

12.5 Provision of equipment and protective clothing

12.5.1 Laboratories used for manipulation of unsealed radioactive substances will need equipment kept specifically for this purpose. This equipment should include:

(a) Tongs, forceps, trays and appropriate apparatus for remote handling (required by AC1/138 – see 12.6.11).

(b) (i) Containers for radioactive substances incorporating the necessary shielding as close to the source as possible.
(ii) Double-walled containers (the outer wall being unbreakable) in which to keep liquid samples.

(c) A drip tray (see 12.6.2).

(d) Compression bulbs or other remote means of operating pipettes; alternatively, hypodermic syringes to replace pipettes.

(e) Syringe shields (see 12.6.12).

(f) Squeezable polythene wash-bottles.

(g) Radiation and contamination monitoring equipment (the latter is required by ACl/149(d) in controlled and supervised (intake hazard) areas for checking clothing, hands and body).

(h) Equipment for the assay of stock solutions.

12.5.2 Appropriate protective clothing and certified respiratory protective equipment must be provided unless the other control measures afford adequate protection (Reg 23). Respirators are not normally needed in research though they may be for dealing with some emergencies (see 16.2.6). Protective clothing will, however, be required in some working areas in order to protect the wearer against contamination of his body or clothing as well as helping to prevent the transfer of contamination to other areas. Protective gowns, presenting an unbroken front surface, and head coverings should be provided for use in controlled (intake hazard) areas. For these areas there should also be adequate supplies of suitable gloves and footwear (ACl/172). Gloves should be of high quality rubber or plastic, preferably disposable; overshoes will usually be suitable as footwear. Clean laboratory coats or overalls, and gloves will be sufficient in supervised areas (ACl/173).

12.5.3 'Protective clothing should be thoroughly washed, cleaned or renewed as often as may be appropriate' (ACl/174) (see 12.8.14 and 15).

12.6 General procedures in laboratories

12.6.1 It is essential that detailed local rules for handling unsealed radioactive substances are drawn up. They must be supplemented by careful training and instruction of staff at all levels (see 2.7.1). It is essential that new procedures and changes in procedures are approved from the point of view of radiological protection by the radiation protection supervisor and, where necessary, by the radiation protection adviser.

12.6.2 Working procedures should be designed to minimise the spread of contamination from the working area. This is necessary not only in the interests of the safety of persons but also to prevent interference with measurements of radioactivity. All operations in grade 1 or grade 2 laboratories involving the production of vapour, spray, dust or radioactive gas, whether necessarily or accidentally, should be carried out in a fume cupboard or in a glove box. The preferred method of evaporation is from above, by means of an infra-red lamp, since this reduces the risk of splashing and spraying. In order to minimise the spread of contamination due to breakages or spills, all operations should be carried out over a drip tray.

12.6.3 To prevent the direct transfer of radioactive substances into the body, the controlling authority should ensure that no eating, drinking, smoking or applying of cosmetics, takes place in the area (ACl/182(a)*). No food or drink should be brought into the area, for example for storage in a refrigerator, nor open packets of cigarettes.

12.6.4 There should also be a ban on the use of handkerchiefs and an adequate supply of paper tissues should be provided to replace them (ACl/182(c) and 183*). For convenience there should be a wall-mounted dispenser. Used tissues should be considered as low-level radioactive waste and placed in a suitable receptacle (see 12.3.13(e) which should be emptied daily (ACl/183*) (see 15.2.5(e)).

12.6.5 Any cut or break in the skin should be covered before a person enters the area (ACl/184*). Dressings should incorporate a waterproof, adhesive strapping. Anyone sustaining a cut or other break in the skin while in the area should go immediately to the radiation protection supervisor who will arrange for first aid to be given (ACl/185) (see 12.8.4).

12.6.6 Anyone working in or visiting the area should wear the protective clothing provided (ACl/169*) (see 12.5.2). On leaving a controlled area the protective clothing should be removed and, if contaminated† (or disposable), placed in the container provided (see 12.3.13(c)). Except in emergencies, protective clothing may not be worn outside the area (ACl/178). Contaminated† clothing should be taken off and placed in the container on leaving a supervised area (ACl/173 and 180). The method of removing gloves should be based on the surgical technique so as to avoid transferring activity to the hands or to the inner surfaces of re-usable gloves; this applies also when putting on re-usable gloves. Protective clothing, except disposable gloves, should be monitored before removal. If re-usable gloves are found to be contaminated they should be cleaned in the wash-up sink and re-monitored before removal. Defects in protective clothing must be reported by the wearer (Reg 23).

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*Approved Code requirement for controlled and supervised (intake hazard) areas.

†See 12.7.4.

12.6.7 Everyone leaving the area should, after removing protective clothing, wash his hands and then monitor his hands, clothing and body (ACl/178 and 179*) (see 12.7.5). Soap, non-abrasive nail brushes and towels or hot air drying equipment should be provided (ACl/151). Towels should preferably be disposable.

12.6.8 When equipment is provided specifically for the safe handling of unsealed radioactive substances, it is essential that it is used. Such equipment should not be moved from the working area. Pipettes, wash-bottles, and similar equipment should never be operated by mouth (ACl/182(d)*).

12.6.9 Glass blowing should be avoided in the laboratory. Where such work is necessary, blowing by mouth is not permissible.

12.6.10 The working area should be kept free of articles not required for the work (ACl/147). This will make it much easier to control surface contamination.

12.6.11 It is essential to keep the working area thoroughly clean and tidy. The standard of cleanliness in a laboratory used for radioactive work needs to be much higher than normal. The walls, floor and ceiling and all apparatus in the area should be cleaned often enough to ensure that any contamination is kept as low as reasonably practicable (ACl/136). If at any time it is found that contamination exceeds the levels shown in Table A4.1 immediate action is necessary (see 12.8.6). Cleaning methods should be chosen so as to minimise the spreading of surface contamination and the creation of airborne contamination (ACl/136). It is therefore essential to avoid raising dust. It is essential that articles used for cleaning controlled or supervised (intake hazard) areas are restricted to these areas and not used elsewhere. They should be monitored periodically, and if necessary, disposed of as radioactive waste. Cleaning and contamination control may be simplified by using disposable items and by covering benches and the interior of drip trays with absorbent material such as plastic-backed absorbent paper. Such contaminated disposable items should normally be treated as radioactive waste after use (see Chapter 15), and they should be removed with forceps or while wearing gloves.

12.6.12 It is essential also to take precautions against external radiation unless only α-radiation is present. Beta radiation and bremsstrahlung should be considered as well as gamma radiation. No article containing a radioactive substance should be handled directly if the resulting dose rate to the skin (averaged between the depths of 5 and 10 mg cm^{-2}) could exceed 0.1 mSv h^{-1} (10 mrem h^{-1}); forceps, tongs, etc, should be used (ACl/138). Use should be made of local shielding, such as a wall of lead bricks, and extra shielding of a radionuclide generator will often be necessary. Syringes used for handling gamma or high energy beta emitters should be shielded.

12.6.13 The total activity handled or stored in a particular working area should not exceed the value for which the area has been designed, that is, the appropriate value shown in Table 12.1 multiplied by the agreed operational factor (see 12.3.5). These activity limits should be specified in the local rules. The radiation protection adviser should be consulted in particular cases where it is desired to use larger activities than those specified. However, it should also be remembered that since the hazard may depend on the chemical form of the radioactive substance, it may be necessary to restrict the activity to less than the general limit in some cases.

12.6.14 So far as possible, a radionuclide having the lowest radiotoxicity, and in the least hazardous form, should be selected for any particular project. The work should be carried out with the smallest activity which it is feasible to use.

12.6.15 Wherever possible, a preliminary experiment should be carried out with inactive materials so that any difficulties in handling the active samples may be foreseen.

12.6.16 It is essential that all radioactive preparations are clearly marked with details of the chemical compound, radionuclide, activity and date. The radiation sign should also appear on the container. All reagents, tools and portable apparatus should be clearly labelled and should not normally be removed from the laboratory.

12.6.17 It is strongly advised that manipulative work with radioactive materials should be carried out only during normal working hours, when full emergency facilities are available. The counting of samples of low activity is excluded from this recommendation. If it is essential to carry out work with radioactive materials after working hours there should always be two persons in the laboratory.

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*Approved Code requirement.

12.6.18 The means of minimising the contamination of working areas must be maintained (Reg 21) and there are specific requirements to maintain ventilation systems and enclosures (ACl/134), changing and storage areas for protective clothing (ACl/149) and washing facilities (ACl/150). Maintenance work on fume cupboards and glove boxes (such as the changing of filters) and on sinks and wastepipes should be carried out under the radiological supervision of the radiation protection supervisor.

12.6.19 It is essential that specialised equipment for handling radioactive substances is routinely serviced.

12.7 Monitoring of laboratories

12.7.1 General guidance on monitoring, including the choice, provision and testing of monitoring instruments, is given in Chapter 4.

12.7.2 It is essential that laboratories in which work with unsealed radioactive substances is undertaken are monitored both for external radiation and for surface contamination, on a regular and systematic basis. For each controlled or supervised area there should be a monitoring schedule (see 4.3.2); for other areas less frequent monitoring is acceptable but it is nevertheless essential that such areas are not overlooked. Adjacent rooms and corridors should also be monitored periodically. Changing areas need special attention. The purpose of such monitoring is to establish the adequacy, from the point of view of radiological protection, of current working methods, to confirm that the designation of certain areas as controlled and supervised areas is correct, and to provide experience in the light of which new techniques may be safely introduced. It can also prevent errors in technical measurements resulting from the contamination of low activity samples. Monitoring results, in particular the details specified in the monitoring schedule, should be properly recorded for future reference.

12.7.3 Monitoring for external beta- and gamma-radiation should be instituted when work is undertaken with unsealed radioactive substances (other than tritium) having an activity greater than about 50 MBq (1.4 mCi) or when radionuclide generators are used.

12.7.4 Derived limits for surface contamination are given in Appendix 4. Contamination above these levels is referred to in these guidance notes as 'excessive' and advice on the action to be taken is given in 12.8. Since contamination should be kept as low as reasonably practicable, monitoring should not merely aim to detect contamination which exceeds the derived limits.

12.7.5 Contamination monitoring will be required for:

(a) All working surfaces (including the interior of enclosures), tools, equipment and the floor of the laboratory. Any items removed from the area should be monitored. Monitoring is necessary during maintenance of fume cupboards, ventilation systems and drains. Direct monitoring should be the rule but, where this is not practicable, wipe testing should be used. Unless other information is available, it should then be assumed that only 10% of the total contamination has been transferred to the swab.

(b) Protective and personal clothing, including shoes, particularly when persons leave a controlled or supervised (intake hazard) area (see 12.6.7). To encourage regular use, a monitoring instrument should be placed near the exit (see 10.6.1(g)).

(c) The hands after work and before eating, drinking, smoking, or the application of cosmetics. An instrument for monitoring the hands should be available where the hands are washed. This monitoring should extend to other skin areas, such as the face, if there is any reason to suspect that these areas may have become contaminated. Care will be necessary in the measurement of low levels of skin contamination since, with some instruments, the contamination can be satisfactorily measured only if the levels of background radiation are commensurately low.

12.7.6 Contamination monitoring for tritium is particularly difficult because of the very low energy of the emitted beta-particles. Removable contamination may be determined by wiping an area of the surface with filter paper or other suitable material, transferring the swab immediately to a vial containing scintillator liquid and measuring the activity on the swab by liquid scintillation counting. The radiotoxicity of tritium, however, is very low and good laboratory practice will usually reduce the need for monitoring to occasional measurements where activities of the order of 1 GBq (a few tens of millicuries) or less are routinely manipulated.

12.7.7 Air monitoring will not usually be necessary if full use is made of fume cupboards or glove boxes. It may be needed under special conditions, defined by the radiation protection adviser. In the event of an emergency involving a serious spill (see Chapter 16) those concerned with the cleaning up procedures should, if necessary, wear well-fitting respirators or breathing apparatus appropriate to the radioactivity being handled, so that even under these conditions air monitoring can be avoided.

12.8 Decontamination procedures

12.8.1 Persons working with unsealed radioactive substances should wash their hands thoroughly with mild soap and water before leaving working areas and especially before eating, drinking, smoking, or the application of cosmetics. Particular attention should be paid to cleaning fingernails.

12.8.2 If washing the contaminated skin with soap and water fails to reduce the contamination below that shown in Table A4.1, an appropriate detergent should be tried. The hands should not be brushed vigorously as this might injure the skin, nor should chemical treatment be attempted for the same reason.

12.8.3 When 'excessive' contamination of parts of the body, other than the hands, is suspected, or when the procedures described above are ineffective, the radiation protection supervisor of the relevant department and the head of the department should be notified at once. Special care needs to be taken in the decontamination of areas near the eyes and in preventing spread of contamination to other parts of the body (for instance, showerbaths should be taken only after the major areas of contamination have been cleansed).

12.8.4 If the skin is broken or a wound is sustained in conditions where there is a risk of radioactive contamination, the injury should be irrigated immediately with tap water. As soon as the first aid measures have been taken, the person should report to the 'appointed doctor' for further treatment, including decontamination if necessary. In such cases it is essential that details of the incident are recorded in the medical records. Advice on medical treatment is given, for example, in the 'Manual on early medical treatment of possible radiation injury': IAEA Safety Series No. 47.(73)

12.8.5 A notice listing the above procedures should be displayed in the laboratory for reference in case of accidents or spills.

12.8.6 If buildings or fittings are found to be 'excessively' contaminated, prompt action should be taken to prevent dispersal of the activity, particularly its transfer to the clothing or body of any person. Contaminated equipment and areas of walls and floors should be isolated and small objects transferred to containers using tongs and gloves. Arrangements should then be made to reduce the contamination and normal cleaning may need to be supplemented by special methods.

12.8.7 Paintwork should be cleaned with detergent and water or, in cases of severe contamination by a long-lived nuclide, removed with a paint remover. Polished linoleum and epoxyresin floor coverings should be cleaned with detergent and water. Polythene emulsion-coating on vinyl floor coverings should be removed with hot water. Water and other materials used for decontamination should be treated as radioactive waste (see Chapter 15). For short-lived radionuclides, if activity still remains, the surface should be suitably covered until the radioactivity has decayed to a level below the relevant limit of Table A4.1; sisalcraft paper is very suitable for this purpose. In the case of high levels of contamination with long-lived radionuclides it may be necessary to remove and replace the floor surface.

12.8.8 Glassware should preferably be cleaned with an alkaline detergent immediately after use. If the contamination has been allowed to dry, the glassware should be marked and segregated for special attention when cleaning. Glassware and porcelain can usually be cleaned by ammonium citrate, chelating agents such as EDTA, or proprietary solutions. The solutions used for cleaning should never be returned to the stock bottle.

12.8.9 Dilute nitric acid can be used to clean plastic, since it will usually be effective without damaging the material. Care should be taken to avoid the use of ketonic solvents and certain chlorinated hydrocarbons.

12.8.10 Contaminated metal tools, trays, sinks, and equipment may be cleaned by washing with a heavy-duty detergent of the type used for laundering, followed if necessary by inhibited phosphoric acid, or by dilute sulphuric acid, or by mixtures of citrates with EDTA or ammonium oxalate. For stainless steel, hydrochloric acid should be avoided as it is likely to corrode the equipment. When other procedures fail with stainless steel, a mixture of six per cent nitric acid with 1 per cent sodium fluoride may be used. In all cases, the cleaning agent should be used only for a minimum time, otherwise corrosion of the equipment is likely to occur thus causing greater difficulty in future decontamination. Stubborn contamination may often be removed by the use of a slightly abrasive polish but only at the expense of some damage to the surface.

12.8.11 Attempts at decontamination may not reduce the activity of equipment and glassware to levels acceptable for continued operation. In this case, if long-lived radionuclides are concerned, the items must then be regarded as radioactive waste (as defined in Section 18 of the Radioactive Substances Act 1960). For short-lived radionuclides, it may be feasible to store certain articles until the radioactivity decays sufficiently. However, in either event, care must be taken to ensure that the proposed action does not contravene the requirements of that Act for the accumulation or disposal of radioactive waste (see Chapter 15).

12.8.12 Following severe contamination it may be necessary to change the designation of the area while it is being decontaminated. A temporary change in the designation of the area may also, with the consent of the radiation protection adviser, allow work to continue in a contaminated area. This should be allowed only if attempts to decontaminate the area have been unsuccessful and it is not practicable to wait until the activity has decayed naturally.

12.8.13 While awaiting laundering it is essential that protective and personal clothing of staff which is known to be, or is suspected of being, 'excessively' contaminated is placed in a container provided for such articles (see 12.6.6).

12.8.14 It is essential that contaminated clothing is not sent to public laundries unless the activities, averaged over an area not exceeding 300 cm^2, are everywhere below the derived limits given in Table A4.1.

12.8.15 Articles contaminated with short-lived radionuclides above the limits given in Table A4.1 should be stored in impermeable bags until the level has fallen to an acceptable value. Care should be taken to prevent airborne contamination during the movement of such contaminated clothing. When storage is not practicable but special laundering facilities are available, contaminated garments with an activity above the derived limits should be given a series of hot rinses in commercial laundry detergent, alternating with rinses in clear water. If the contamination persists, the article should be washed in a hot solution of 1.5 per cent citric acid followed by a series of cold rinses. An automatic washing machine is very useful for this purpose. Clothing which cannot be laundered satisfactorily or be held for storage should be treated as radioactive waste.

12.8.16 Clothing should be monitored before re-use to ensure that decontamination has been successful.

12.9 Field work

12.9.1 Proposals for staff or students of a research or teaching establishment to use unsealed radioactive materials outside the establishment, or anywhere in the open air, should be discussed in advance with the radiation protection adviser and with the Radiochemical Inspectorate of the Department of the Environment. The project should be one which cannot be realised in a laboratory, for example, tracer studies on crops or on silting, and the smallest practicable activities of short-lived radionuclides should be used whenever possible.

12.9.2 The work must be carried out in accordance with a special registration prepared by the Radiochemical Inspectorate. In assessing the radiation impact of the work, it may be necessary to assume that all radioactive materials used pass into the environment.

13 The use of animals

13.1 Scope

13.1.1 This chapter describes some of the additional precautions which are necessary when unsealed radioactive substances are administered to animals. It should be read in conjunction with Chapter 12. (See also 2.2.11).

13.1.2 Where animals are irradiated with radiation beams, guidance is given in Chapter 6. For radiography and fluoroscopy see the veterinary guidance notes.(124)

13.2 Hazards

13.2.1 Some of the administered activity is likely to be excreted in the animal's urine, faeces or breath, resulting in the following hazards to those working with animals:

(a) inhalation and ingestion of radionuclides absorbed on dust particles arising from bedding materials;

(b) inhalation of radioactive gases exhaled by animals;

(c) contamination of skin by animal excretions.

13.2.2 Radioactivity could enter the body of persons handling animals through contaminated wounds which are due to bites, scratches or accidents with hypodermic needles used for administration by injection.

13.3 Housing of animals

13.3.1 Small animals to whom unsealed radioactive substances have been administered, and who are to be kept alive for more than a few hours, should be housed in a room which is separate from, but near, the laboratory. The room should meet the standard of a grade 3 area (or of a grade 2 area if larger activities are in use — see Table 12.1), including easily cleaned surfaces, good ventilation and washing facilities. The floor should fall away to a drain so that the room can be readily washed down rather than swept out.

13.3.2 Cages should be made of easily cleaned materials, such as plastic, aluminium or stainless steel.

13.3.3 Non-dusty materials should be used for bedding such as cellulose wadding, absorbent paper or coarse grain vermiculite. Coarse sawdust or wood shavings may be used for low activity work (that is, one or more orders of magnitude below the limit for a grade 3 area).

13.3.4 Large animals should be kept in pens which can be cleaned by hosing down or mopping out. Delay tanks may be required where large activities are involved.

13.3.5 Where it is necessary to collect excreta for analysis, the cage used should be constructed so that it can be easily dismantled for cleaning.

13.3.6 If ^{14}C or ^{3}H labelled compounds which are metabolised to gaseous products are administered in large (for example, grade 2) quantities, the cages should be placed in fume cupboards or glove boxes. Alternatively, the animals should be placed in metabolic cages designed for use with exhaled gases.

13.3.7 Cages may need to be shielded if gamma emitters or high energy beta emitters are administered.

13.3.8 Animals which are not part of experiments involving radioactivity should not be housed in the same area.

13.4 Laboratories and other areas

13.4.1 Laboratories for the preparation and administration of radioactive substances should be designed in the way described in 12.3. A glove box with weighing and mixing facilities should be provided if radioactively labelled diets are to be prepared.

13.4.2 An area should be provided for the cleaning of cages.

13.5 Animal handling procedures

13.5.1 The general guidance on procedures in laboratories (see 12.6) applies in all areas where unsealed radioactive substances are present, including areas for the preparation of radioactive solutions and diets, administration, measurements on samples or on whole animals and areas where animals are kept after administration.

13.5.2 Animal technicians who may be unfamiliar with laboratory work must be given training and instruction in the precautions which are necessary during and following the administration of unsealed radioactive sources to animals (see 12.6.1). The radiation protection supervisor should ensure that all personnel handling treated animals understand these precautions.

13.5.3 In addition to gloves a washable apron should be worn. Spread of activity in the animal's urine should be anticipated during handling and surfaces likely to become contaminated should be covered with washable material.

13.5.4 Fluids for injection and syringes should be placed in trays lined with absorbent paper so that any spillage is contained within the tray (see 12.6.11). Syringes may need to be shielded (see 12.6.12).

13.5.5 The animal should be anaesthetised during administration by injection. If this is not reasonably practicable, it should be held firmly to avoid accidents with syringes. Care should also be taken to avoid bites and scratches at all times (see 12.8.4).

13.5.6 The handling procedure should be planned so that the animal and active materials have to be moved through the shortest practicable distance. The animal should be outside its cage for the minimum time.

13.5.7 Unless advised otherwise by the radiation protection adviser, operational factors (see 12.3.5) of 1–0.1 for administration and 100–10 for measurements on animals, using for example a gamma camera or scanner, should be used.

13.6 Procedures in animal houses

13.6.1 Following administration, the animal's cage or pen should be labelled to indicate the radionuclide, substance administered, the activity the time and route of administration and the name of the supervisor. Any special directions regarding handling, cleaning and disposal of waste should be displayed on the cage. Labels should be of a type which does not require licking. The information about administration should also be kept in the records (see 14.9).

13.6.2 It is essential that protective clothing is worn. A dust mask which completely covers the nose and mouth should be worn during cage cleaning.

13.6.3 Every effort should be made to avoid the creation of dust, especially when cleaning cages. Cages should be cleaned regularly and frequently since it is more difficult to decontaminate surfaces after deposits have dried. Contaminated bedding, excreta, water from cage or pen washing, and so on, must be treated as radioactive waste (see Chapter 15).

13.6.4 Great care should be taken to prevent the escape of treated animals. At the end of the trial carcasses should be disposed of as radioactive waste (see 15.2.4 (h)).

13.6.5 Cages which have contained treated animals should be thoroughly washed and then monitored. They should if possible be retained for subsequent use with similarly treated animals.

13.6.6 Persons working in animal houses, like those in laboratories, should follow the guidance of sections 12.8.1 to 12.8.5 on personal washing and decontamination.

13.7 Pathological and post-mortem examinations

13.7.1 When high energy beta emitters are involved, it is essential to protect the hands against beta radiation when the animal's body is opened. If the gloves are cut or torn and the hands are injured the advice given in 12.8.4 should be followed.

13.7.2 Precautions should be taken against contamination from body liquids.

13.7.3 At the conclusion of the examination surgical instruments and equipment should be thoroughly checked for contamination and, if necessary, decontaminated.

14 Storage and movement of radioactive materials

14.1 Principles

14.1.1 Radioactive materials which are not in use should be kept in a properly designed store unless their removal from the working area is likely to result in a greater hazard to the persons concerned.

14.1.2 The arrangements made should provide security against loss or theft and damage by fire as well as protection against radiation hazards.

14.2 Responsibility

14.2.1 While overall responsibility for safe storage for radioactive materials rests with the controlling authority, it may often be found beneficial to appoint a custodian to be responsible for organising the security during storage and use of all radioactive materials at the establishment and for ensuring that all necessary records are kept. The custodian may be the radiation protection adviser if this is found to be convenient. (See also 2.2.3 regarding supervision.)

14.2.2 At larger establishments it is recommended that one or more persons should be appointed in each department in which radioactive materials are stored. This person or persons would be directly responsible under the custodian of radioactive substances for the receipt, storage, maintenance and issue of radioactive materials.

14.2.3 If no custodian is appointed, or if there is no specific person responsible to him, the duties assigned to them in these guidance notes will still need to be performed. However control is organised, the responsibilities of the persons involved should be defined in the local rules.

14.2.4 It is essential that radioactive materials issued from a store are at all times, until their return or disposal, in the care of responsible individuals. The local rules should define precisely the responsibility of such individuals.

14.3 Provision and design of stores

14.3.1 Radioactive material which is not in use must, so far as is reasonably practicable, be kept in a suitable receptacle and in a suitable store (Reg 26). The terms of registration under Section 1 of the Radioactive Substances Act 1960 will normally include a similar requirement. As long as it meets the criteria for suitability set out in 14.3.2–10, the store may be a place set apart from the work or it may be a cupboard, safe, drawer or similar unit within the working area. In general, the former will be preferable for long-term storage and the latter for short-term storage. It may, therefore, be necessary to provide both types of store.

14.3.2 The store should, so far as is reasonably practicable, be reserved for radioactive materials, their immediate containers and receptacles, and immediately ancillary items such as handling tools and shielding materials (AC1/196).

14.3.3 It is essential that stores for radioactive materials are sited and designed so that all persons are adequately protected during both storage and transfer of materials to and from the stores. Stores should therefore, where reasonably practicable, be located near working areas. The store should provide adequate shielding (AC1/197(b)); the radiation dose rate at any accessible position outside the store should not exceed 7.5 μSv h $^{-1}$ (0.75 mrem h $^{-1}$). It is essential that the protection provided within the store is such that the person who transfers materials does not, in the performance of these duties, receive more than small fractions of the dose limits. The radiation dose rate inside the store should not normally exceed 0.2 mSv h $^{-1}$ (20 mrem h $^{-1}$) at 5 cm from any source, source container or shielded compartment for long term storage, or 2 mSv h $^{-1}$ (200 mrem h $^{-1}$) for temporary storage. Data for the computation of shielding are given in BS 4094 (96) .

14.3.4 In providing shielding for radioactive materials it is essential to consider the scattered radiation. It is not sufficient to place large activities behind a barrier, no matter how thick, if the radiation scattered around it presents a hazard.

14.3.5 Consideration should also be given to the location of radioactive materials within a store. If it can be ensured that no materials can be placed close to the outside wall the shielding may be reduced.

14.3.6 Unless only a few closed sources or containers of unsealed radioactive substances are to be stored, or the dose rates in their vicinity are low, a number of separate compartments should be provided in the store so that the total stock can be sub-divided. Each compartment should be so marked as to permit immediate and [illegible] identification of its contents from the outside.

14.3.7 The store should, where necessary, be ventilated by mechanical means (AC1/197(d)). Ventilation will be required when radioactive gas, dust or vapour is liable to be present; this condition may be specified by the Department of the Environment in the Certificate of Registration. The mechanical means may be an extractor fan mounted in an outside wall. The fan should be operated continuously while persons are in the store room or close to an open store cupboard and also for a sufficient time before the room is entered or the cupboard opened. The exhaust point should be well chosen. Filters are unnecessary for the amount of radioactivity normally stored in research laboratories, universities and colleges and are, in fact, undesirable because of the maintenance and disposal problems they create.

14.3.8 Attention should be given to the radiation hazards which may arise from stored radioactive substances in the event of fire and flood. It is essential that the place of storage is chosen and the store constructed with this in mind. Advice on these matters may be sought from the chief fire officer or firemaster (see 2.10.2). The approved code requires that the store should provide appropriate fire resistance and protection against flooding (ACl/197) and the Department of the Environment will usually require that the store is designed and constructed so that every registered source or substance is reasonably protected against damage from fire and that the store contains nothing explosive or readily flammable (registration under the Radioactive Substances Act 1960). An exception may be made to the last requirement in the case of material used as a neutron moderator. However, if paraffin wax is used it should be contained in metal. Water is usually unsuitable since shielding can easily be lost through leakage or evaporation.

14.3.9 Stores should provide adequate physical security (ACl/197(e)) and it is essential that they are securely locked except when it is necessary to enter or open them.

14.3.10 A suitable notice should be displayed outside the store to warn persons in the vicinity (ACl/197). It is recommended that the design should be as illustrated in Appendix 3, Fig. 4. Although it is not essential to list the contents of the store on the notice it can be of help in case of emergency if it is done.

14.3.11 Under certain circumstances it may be necessary to store materials at reduced temperatures. Such materials may be stored in suitable refrigerators or deep freeze units which, if reasonably practicable, should be set aside solely for this purpose and be fitted with locks.

14.4 Storage at place of use

14.4.1 A sealed source may be left inside a piece of fixed equipment, such as an installed exposure container for gamma radiography. Protection against leakage radiation and source security are considered in 6.6.5 and 6.6.9. There should be a radiation warning sign at the entrance to the room or enclosure (see 6.2.7).

14.4.2 Unsealed radioactive substances may be kept inside a fume cupboard or glove box if removal to a store would give rise to hazards. The enclosure or laboratory should be lockable. Where radioactive substances liable to be airborne are stored at the place of use see 12.4.1 and 12.4.5.

14.5 Storage of mobile and portable equipment

14.5.1 Mobile and portable equipment containing sealed sources, such as portable exposure containers and gauges, should, when not in use, be moved to a store (see 8.4.11).

14.6 Special precautions for storage of unsealed radioactive substances

14.6.1 There is a general requirement to consider the suitability of the storage receptacle (ACl/194). This section lists some special precautions when dispersible unsealed radioactive substances are stored.

14.6.2 It is essential that fragile containers, such as glass vials, are, whenever practicable, stored inside unbreakable containers.

14.6.3 It is essential that active residues of all radioactive preparations and solutions are stored in containers, the stoppers of which will not leak but will allow excess pressure of gas to escape.

14.6.4 It is essential that chemically stable solutions containing radioactive substances in excess of 200 MBq (5.4 mCi) of alpha-activity and 2 GBq (54 mCi) of beta activity are stored in properly vented containers. These activities may be expected to produce about 1 millilitre per month of gas at standard temperature and pressure from radiation decomposition of water.

14.6.5 Chemically unstable solutions containing radioactive substances, such as nitric acid or other oxidising solutions containing traces of organic material, peroxides, chlorates, etc., should be stored in vented containers and kept in vented storage areas.

14.6.6 Special care should be taken in opening containers of radioactive substances which have been long in store to minimise the danger from bursting or frothing. They should be opened only in a fume cupboard or glove box over a drip tray.

14.6.7 Highly alpha-active solutions should not be left in thin glass vessels as the glass is liable to weaken under irradiation. It is not possible to state a concentration at which this becomes serious because the main danger is from dry deposits above the liquid surface. It should be borne in mind if the concentration is of the order of 50 MBq (1.4 mCi) per millilitre or more.

14.6.8 Solutions stored in refrigerators or deep freeze units should be in polythene or other suitable plastic containers unless the material has been supplied in a glass container which will not crack at low temperatures.

14.7 Identification, inspection and leakage testing of radioactive materials

14.7.1 Means of identification should, where reasonably practicable, be provided, by number, mark or other appropriate method, on all radioactive material exceeding a minimum notifiable quantity* (ACI/187). Sealed sources and other closed sources having at least one dimension exceeding 5 mm should have been permanently marked by the manufacturer; wire, pins and foil which cannot be marked should be identified by labelling or colour coding (ACI/188). In the case of sources smaller than 5 mm and dispersible radioactive substances, the identification should be on the container.

14.7.2 The identification of the contents should be repeated on the outer container, particularly in the case of unsealed radioactive substances to which 14.6.2 applies. It is essential that all containers are clearly labelled, using a system whereby the contents can be readily identified. The label should bear the radiation symbol (see Appendix 3).

14.7.3 Where two or more types of source have a similar appearance it is essential that a method of discrimination is adopted. A check should be made regularly to verify that the sources are correctly identified.

14.7.4 It is essential that sealed sources are regularly examined by a competent person with sufficient frequency to permit the early detection of progressive damage which might lead to the leakage of radioactive substances.

14.7.5 A leakage test certificate should be obtained from the manufacturer for every sealed source and, if possible, for other closed sources or articles containing radioactive substances exceeding a minimum notifiable quantity. If a certificate cannot be obtained the source should be tested for leakage (ACI/204). Thereafter a leakage test should be made at least every 26 months unless the activity has fallen below the notifiable level. The radiation protection adviser should be consulted on the need for more frequent tests of less robust sources or where there would be a particular hazard from any leakage (ACI/205). However, on account of the resulting radiation dose to the person carrying out the test, unnecessarily frequent testing is undesirable. Sealed sources should be leak tested by one of the methods, appropriate to the type of source, given in Appendix D of BS 5288: 1976 (102) and in DD 66: 1980. (108) These methods may also be used for other closed sources but it is necessary to relax the criteria for freedom from leakage, possibly by several orders of magnitude. Tests should be made thoroughly but quickly, using forceps for holding swabs (as well as the sources themselves), in order to minimise the radiation dose to the operator. In carrying out leakage tests of beta sources care is essential to avoid damaging the window through which the beta radiation is emitted. A record of each test should be kept for three years; the details to be recorded are listed in ACI/208. It is essential that bottles of radiochemicals are tightly closed to prevent leakage until they are opened and confirmatory leakage tests may be needed. Quality assurance tests by the manufacturer may be supplemented by contamination monitoring of the area where radiochemicals are kept. (See also 16.4.6).

14.7.6 Very great care should be taken when carrying out a leakage test on a high output source. The test should be made only by an experienced person making the maximum use of shielding and distance to reduce radiation dose. An installed source should not normally be removed for testing. Instead, the immediate vicinity of the source should be wiped. If the activity measured on the swab is less than 200 Bq (5 nCi) the source may be considered to be leak free. If the activity is greater than this it is essential to make immediate arrangements to prevent the spread of contamination and alter to remove the leaking source and decontaminate the equipment.

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*Minimum notifiable quantity is defined in Appendix 7.

14.8 Maintenance and checking of stores

14.8.1 It is essential that the stores are maintained in an orderly fashion and are inspected regularly by the custodian or by a responsible person nominated by him (see also 14.9.9).

14.8.2 Environmental monitoring should be carried out at regular intervals, and whenever there is reason to think that radiation levels might have changed significantly, in order to ensure that the area designation (see 2.4) remains correct. Radioactive materials may need to be moved temporarily in order to carry out contamination checks at the positions which they normally occupy.

14.9 Stock records and control procedures

14.9.1 The controlling authority must be able to account for all radioactive material under its control at any time during the last two years except that it may be considered not reasonably practicable to do this if the material has an activity less than the notifiable level or a half-life less than three hours (Reg 25 and AC1/190).

14.9.2 A record should be kept of all radioactive materials on the premises having a half-life of more than 12 hours which shows:

(a) distinguishing number, identifying mark or other adequate description;

(b) date of receipt onto the premises;

(c) nature of the radioactive substance;

(d) activity at a specified date;

(e) whereabouts;

(f) date and manner of disposal (AC1/191).

(AC1/191).

It will also usually be necessary to keep the same information for each registered source or substance as a condition of registration under the Radioactive Substances Act 1960. It may be useful to add further information to the record, such as a more detailed description of the source or unsealed material. Entries should be made relating to examinations, leakage tests and repairs; alternatively, leakage test certificates may be attached to the record. For sources smaller than 5 mm and dispersible radioactive substances the above particulars need be recorded only as far as reasonably practicable but there should always be some record of where the radioactive material is kept and of significant losses (AC1/192).

14.9.3 In order to comply with the requirement to record the whereabouts of each item, it is essential that records are kept in each store of radioactive materials received, issued and returned, these records being sufficiently detailed and so arranged that information concerning the precise whereabouts of every closed source which has been issued, and its expected time of return, is immediately available. The possibility of supplementing written records with a convenient visual display system should be considered. This additional record of day-to-day whereabouts is not necessary for sources which are in a permanent recorded position.

14.9.4 It may be convenient and may assist stock accountancy, particularly of radionuclides of comparatively short half-life, to record volumes rather than activities, of radioactive solutions dispensed. A record of both the initial activity and the initial volume will then be needed.

14.9.5 Where radionuclide generators are used there should be:

(a) a record showing the receipt of new generators and the return of spent ones, and

(b) a record of use for each generator showing the date, time and activity of each elution.

14.9.6 Whenever radioactive materials are moved in or out of store, or are transferred to the care of a person in another department or area, it is essential that the recipient signs a receipt as a record of the transfer.

14.9.7 It is essential that, at regular and frequent intervals, the custodian or the person(s) responsible for the store(s) undertakes an audit to account for every item listed in the records. Sources in the store should be counted (without necessarily checking serial numbers) except that a previous count may be accepted for a group of sources which have been stored in a sealed container since the previous audit. It is essential that sources which have left the store are covered by a current receipt. The stock of unsealed radioactive substances should be inspected to ensure that it agrees with receipts, issues and disposals, where necessary taking into account radioactive decay.

14.9.8 The location of all items in the records should be physically checked at least once in every 14 months and their whereabouts re-recorded (ACI/193). It is essential that this annual check audit is undertaken by a senior officer nominated by the controlling authority.

14.9.9 Radioactive material which is no longer required should not be retained unnecessarily. It should be declared radioactive waste and arrangements should be made for its disposal (see 15.2.5). In addition to a continuing assessment, the need to retain each item on the register should be positively reviewed during the annual audit.

14.10 Internal movement of radioactive materials

14.10.1 A radioactive substance should be considered to be transported if it is moved more than ten metres [this may be amended when ACI/199 has been agreed]. It must, where reasonably practicable, be in a suitable receptacle while being transported (Reg 26). It is essential that such receptacles or containers are designed:

(a) to provide adequate protection for all persons during loading, transport and unloading,

(b) to prevent loss of radioactive substances,

(c) to minimise the risk of spilling unsealed radioactive substances or releasing airborne or gaseous activity.

Storage containers, particularly those for unsealed radioactive substances, may not be sufficiently robust to withstand transport shocks and will therefore require additional physical protection.

14.10.2 The container should be clearly marked to indicate that its contents are radioactive. The label should carry the warning sign described in Appendix 3. When unsealed radioactive substances are transported the label should indicate their nature and activity. Radioactive materials may alternatively be moved within the establishment in the packaging for external transport (see 14.11 and Appendix 5).

14.10.3 Radioactive materials should be transported by, or under the supervision of, a trained person. If the transported item is handed over to another person, that person should be made aware of its radioactive nature. He should give a receipt for it in order to record its whereabouts. In any case it is essential that the item is not left unattended.

14.10.4 Articles and equipment which contain radioactive sources should carry a suitable warning notice. If the contents are secure there will be no need to place such items in containers for internal transport.

14.10.5 Care should be taken that radioactive materials are not moved inadvertently.

14.10.6 If it is necessary to pass along or cross any road to which the public has access when moving radioactive materials in a vehicle from one part of the establishment to another, the requirements for external transport apply.

14.11 External transport of radioactive materials

14.11.1 The transport of radioactive materials outside the establishment must or should, as appropriate, be in accordance with the current national and international regulations and codes of practice relating to the various means of transport used (see paragraph 2 of Appendix 5). The materials should be packaged in accordance with the International Atomic Energy Agency (IAEA) Transport Regulations (65, 72) (ACI/201).

14.11.2 Where goods are transported by an independent carrier, the radiation protection supervisor of the consigning department should ensure that they are properly packaged and labelled. The principal requirements are shown in Appendix 5. A consignor's certificate may be required and the consignee should be advised.

14.11.3 If the establishment wishes to act as carrier, it is essential that the controlling authority lays down an appropriate procedure, in conformity with the Radioactive Substances (Carriage by Road) (Great Britain) Regulations 1974 (40)* and the Codes of Practice for the Carriage of Radioactive Material by Road (114) and for the Storage of

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*In Northern Ireland, the equivalent regulations.

Radioactive Material in Transit (115), after consultation with the radiation protection adviser. It may be necessary to designate a controlled area or a supervised are within the vehicle and possibly, while the vehicle is stationary for a prolonged period (at least one hour), outside the vehicle (AC1/63).

14.11.4 For incoming radioactive goods, suitable arrangements should be made to ensure that all persons are adequately protected. Packages should be opened only by persons having the necessary knowledge and in a suitable area. While waiting to be opened, packages should be properly stored bearing in mind that those with yellow labels may require additional shielding for other than temporary storage.

[The requirements of the Approved Code with regard to internal and external transport are under further consideration.]

15 Disposal of radioactive waste

15.1 Legal requirements

15.1.1 Radioactive waste, except for some minor activities which are exempt, may be disposed of or accumulated only in accordance with the conditions specified in an authorisation under the Radioactive Substances Act, 1960 (see 2.2.4). The conditions will include specification of:

(a) the method(s) of disposal which may be used,

(b) the maximum activities or activity concentrations of the waste which may be disposed of in a particular period,

(c) the containment of the waste while awaiting disposal,

(d) the maximum time during which waste may be kept,

(e) the records which are to be kept.

15.1.2 It is the duty of the controlling authority to ensure that an authorisation is obtained, to specify local rules to ensure that its conditions are observed, and to check periodically that the rules are being followed. If waste is likely to arise in several areas or departments, the controlling authority will need to ensure sufficient co-ordination of the arrangements covered by the same authorisation. It may be advisable to arrange departmental allocations of the permissible total activities.

15.1.3 Disposals of minor activities of radioactive waste have, subject to certain conditions, been exempted by orders from the authorisation requirements. Exemption orders which are particularly relevant to radioactive waste arising in research and teaching are referred to in 15.3.

15.1.4 General guidance is given in 15.2 but, in following it, it is necessary to ensure that the action taken is in accordance with an authorisation or an exemption order.

15.2 General guidance on the disposal of radioactive waste

15.2.1 General policy on waste disposal is based on the White Paper 'The Control of Radioactive Wastes' (Cmnd 884) (119) and on the report, issued in 1979, of an expert group set up by the Department of the Environment's Radioactive Waste Management Co-ordinating Committee to review Cmnd 884. (120) Low level radioactive waste is best disposed of by the methods used for ordinary waste:

(a) Local authority refuse service for solid waste

(b) Sewers for aqueous liquid waste

(c) Emission to atmosphere for gaseous waste.

If precautions are taken, incineration is also an acceptable method of disposal (see 15.2.5 (d)(iv)).

Waste which, either for radiological or for other reasons, is unsuitable for local disposal may be disposed of by:

(a) Return to manufacturer, etc. (particularly for closed sources).

(b) Burial on an approved tip.

(c) National Disposal Service.

The White Paper gives some guidance on the levels of activity which can in general be disposed of with ordinary waste. The authorisations and the conditions they impose are based on this general guidance but they have regard to the local conditions, which may affect permissible levels. Local conditions vary so widely that general conditions may frequently be modified.

15.2.2 Advice on all aspects of waste disposal, including particulars of the National Disposal Service for which there are special requirements on segregation and packing of waste, may be obtained from the Radiochemical Inspectorate of the Department of the Environment.*

15.2.3 If the waste contains radionuclides of short half-life, the activity to be disposed of can be reduced naturally by storing the waste for a suitable period. The hazards associated with storage will need to be considered and accumulation of the waste will require authorisation unless an Exemption Order applies, in which case accumulation will be subject to the conditions specified in that Order.

15.2.4 It is convenient to recognise the following types of radioactive waste which may occur in research and teaching:

(a) Sealed sources and other closed sources.
(b) Unwanted solutions of radionuclides.
(c) Normal low-level liquid waste, for example, from washing of apparatus.
(d) Unwanted solid radioactive material in dispersible, unsealed form.
(e) Normal low-level solid waste, such as paper, glass.
(f) Articles and plants which have been used in tracer experiments.
(g) Filters from exhaust systems.
(h) Animal carcasses.
(i) Liquids immiscible with water, such as liquid scintillation counting residues or contaminated pump oil.
(j) Flammable waste.
(k) Waste from spills and accidents.
(l) Gases.
(m) Spent radionuclide generators.

15.2.5 (*a*) Waste closed sources, for example sealed sources whose activity is no longer sufficient because of decay, old electronic valves which are classed as 'radioactive' and gaseous tritium tubes, may present a hazard if set aside unlabelled and forgotten. They should be clearly labelled and, if of short half-life, stored until by decay the activity is reduced to a level which permits disposal with ordinary waste, or they should be disposed of at once either by returning them to the manufacturer or other specified person or through the National Disposal Service. A decision should be taken as soon as such items are recognised as waste and action taken to implement the decision with reasonable speed. A sealed source which has reached the end of its working life, as recommended by the supplier, should be removed from service and treated as waste. It is essential that any sealed source which is found to be leaking is immediately taken out of service and either aired or disposed of.

(*c*) Many laboratory radiochemicals will be in the form of aqueous solutions. ivities of unwanted solution may be disposed of through laboratory drains to a main sewer (see 12.3.13 (f)). A comparatively large volume of water should be allowed to flow through the drain to dilute the waste and minimise retention in U-traps. Liquid waste of low activity, resulting from simple laboratory operations or the washing of apparatus, is usually suitable for immediate disposal to the sewer.

(*d*), (*e*) and (*f*)

(i) Solid waste, such as contaminated paper tissues, swabs, glassware, and similar materials, is usually of low activity, not exceeding about 100 kBq (that is a few microcuries), and is therefore suitable for disposal with ordinary refuse.

(ii) More active items, comprising unwanted radioactive material which is not in the form of a closed source and more heavily contaminated articles, should not be allowed to pass into normal refuse bins but should be segregated for special disposal. This type of waste will either have to be taken to an approved tip where it is immediately buried under 1.5 m of non-active material or, if the activity is too great for this, disposed of through the National Disposal Service.

(iii) Any items attractive as salvage should be physically destroyed before disposal with ordinary refuse or at a special tip.

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*Or, as appropriate, the Environment Protection Unit, Welsh Office, HM Industrial Pollution Inspectorate for Scotland, Scottish Development Department, and the Alkali and Radiochemical Inspectorate for Northern Ireland, Department of the Environment for Northern Ireland.

(iv) Some combustible low-level waste contaminated with relatively low-toxicity materials which burn to give entirely gaseous products, such as tritium, ^{14}C or ^{35}S, can be burned with ordinary refuse in a good incinerator if there is adequate dispersal of the radionuclides in the atmosphere. Where this method is used, the waste should be packed in sealed containers which are fully combustible. Incineration of wastes containing non-volatile radionuclides may concentrate the radioactivity in the ash, and ash of undesirably high activity in a not easily controllable state may be produced.

(*g*) Filters which have been removed from exhaust systems should be sealed promptly in bags to prevent redispersion of radioactive particles and disposed of as solid waste.

(*h*) The carcasses of animals to which radioactive substances have been adminstered may be disposed of by incineration. The siting and chimney height of the incinerator should be well chosen and the ash disposed of as low-level solid waste. Small animals should preferably be disposed of by maceration in a laboratory disposal unit reserved for the purpose as this avoids the necessity to dispose of ash. It is frequently advisable to store the carcass for a suitable period to allow short-lived radioactive substances to decay. Advice on the temporary preservation of radioactive animal carcasses is given in Appendix 6.

(*i*) Liquids which are immiscible with water, such as scintillation-counting residues, should not be disposed of to the drains; alternative methods of disposal, such as incineration, either on the premises or by a contractor, should be used. Contaminated oil should be placed in marked drums and disposed of by a specialised service.

(*j*) The greatest efforts should be made to avoid the creation of flammable radioactive waste. When such waste does arise it should be placed immediately in a fireproof container pending removal from the site.

(*k*) The method of disposing of radioactive waste arising from spills and accidents will depend on the nature of the incident. So far as it is reasonably practicable, consistent with the safety of the staff involved and the urgency of the decontamination measures, the radioactive waste resulting from the cleaning up operations should be retained in suitable containers unless it is clear that the activity is low enough to permit immediate disposal. If it is not, or has not been, possible to prevent excessive activity from entering the drains, a large volume of water should be allowed to flow to provide dilution. After the immediate emergency is over, the activity of the resulting waste should be assessed and heavily contaminated swabs and other items set aside for storage or special disposal. It is essential that the Radiochemical Inspectorate of the Department of the Environment* is informed as soon as possible if waste of activity exceeding that specified in an authorisation certificate has arisen.

(*l*) In general, gaseous wastes resulting from research and teaching uses of radioactive substances, such as exhausts from stores and fume cupboards and emissions from incinerators, should be discharged in such a manner as to prevent re-entry into any part of the premises. This condition is usually laid down in the authorisation certificate. It is important therefore that the points of release to the atmosphere should be carefully sited (see also 12.4.2 and 12.4.5). Radiation and contamination levels near discharge points should be checked periodically by the radiation protection supervisor of the relevant department.

(*m*) Spent radionuclide generators should preferably be returned to the manufacturer for disposal. If this method is not used, generators should be disposed of through the National Disposal Service or by other approved means. When the half-life of the parent radionuclide is comparatively short, for example, iodine-132 and technetium-99m generators, storage of the spent generator for a further period of natural decay may permit subsequent disposal with ordinary refuse. However, the presence of small amounts of long-lived residual activity will sometimes necessitate unacceptably long storage periods.

15.2.6 It is essential that all radioactive waste awaiting disposal, or stored to allow decay, is kept in suitable containers which prevent any dispersion of the contents. Containers of other than low-level waste for disposal by the local authority, such as dustbins, should be clearly labelled to show the radionuclide(s) and activity on a given date. They should be marked 'radioactive waste' and with the radiation symbol (see Appendix 3). Materials stored prior to disposal through the National Disposal Service should be packed so that they can be transferred without producing further hazard or contamination of the ultimate disposal container.

*In Wales, the Environment Protection Unit, Welsh Office, in Scotland, HM Industrial Pollution Inspectorate for Scotland, Scottish Development Department, and in Northern Ireland, the Alkali and Radiochemical Inspectorate for Northern Ireland, Department of the Environment for Northern Ireland.

15.2.7 While decaying and/or awaiting disposal, radioactive waste should be stored in accordance with the requirements and advice given in Chapter 14, either in a store used for useful radioactive materials or in a store reserved for radioactive waste. The storage record called for in 14.9.2 should be continued, or started, but should be endorsed 'radioactive waste'.

15.2.8 It is essential that all disposal is properly supervised and carried out with the knowledge of the radiation protection supervisor. A record of the disposal should be made to satisfy the requirements of the authorisation certificate or Exemption Order. The storage record should be closed.

15.2.9 Empty containers which have been used for radioactive material may, if uncontaminated, be disposed of freely, but it is essential that all labels which might indicate radioactivity are removed or obliterated.

15.3 Exemption Orders

15.3.1 Under the Waste Closed Sources Exemption Orders (24,25,26) a waste source may be disposed of without authorisation either to a person authorised under the Radioactive Substances Act 1960 to dispose of that type of waste or to a manufacturer of that type of source provided that records are kept showing the radionuclide(s) and its activity, the date of disposal and the name and address of the person who receives the waste source. Waste closed sources must be kept in appropriate containers or stores and disposed of within 12 weeks unless authorisation for a longer period is obtained.

15.3.2 Other Exemption Orders which may be of interest to those in research and teaching include those dealing with:

(a) Luminous articles (12,13,14)
Uranium and Thorium (15,16,17)
Prepared Uranium and Thorium compounds (18,19,20)
Geological specimens (21,31,32)
Electronic valves (30,31,32)
Smoke detectors (33,34,35)

16 Emergency procedures

16.1 Introduction

16.1.1 Contingency plans, described in the local rules, are obligatory where it is reasonably foreseeable that an accident or incident could lead to significant radiation exposure of any person (see 2.10.1). This chapter gives guidance on the circumstances for which such plans are needed and on the action required.

16.1.2 Most incidents involving spills of unsealed radioactive substances do not warrant any drastic emergency action. Simple remedial measures, such as the use of absorbent paper, are often sufficient and should form part of the training of research workers and students. Nevertheless, a more serious incident could possibly occur and some preparation to anticipate the event is necessary. In the present context it is essential to treat an incident as an emergency if it involves the dispersal of more than 300 kBq (8 μCi) of Class 1, 30 MBq (0.8 mCi) of Class 2, 3 GBq (80 mCi) of Class 3 or 300 GBq (8 Ci) of Class 4 radionuclides, or one-tenth of these activities when a gas, vapour or aerosol is concerned. (These are one-tenth and one-hundreth respectively of the activities shown in Table 2.1.)

16.1.3 Emergency procedures are also essential:

(a) in the event of the loss or suspected loss of a closed source or of unsealed radioactive material,

(b) if a closed source is damaged to an extent which involves or might involve, the dispersal of more than the above activities of radioactive material,

(c) if it is not possible to retract a radioactive source, close a shutter or switch off a radiation beam by normal methods, and in the event of malfunction of a research reactor.

16.1.4 It is essential that the local rules cover:

(a) preparations for dealing with an emergency,

(b) action to be taken during an emergency, and

(c) action to be taken when the immediate emergency is over, in accordance with the principles set out in the following sections. The local rules should include the names of persons responsible for implementing the plans and all details of the plans should be kept up to date (AC1/225).

16.2 Preparations for dealing with an emergency

16.2.1 It is essential that the instructions on action to be taken in an emergency cover all the points dealt with in 16.3 which may be relevant and that they are read and understood by all persons who may be concerned. They should be reviewed periodically and revised as necessary.

16.2.2 Care should be taken to ensure that there are adequate means of escape in the event of a fire or other emergency. The local rules should make clear the circumstances in which emergency exits are to be used (see also 2.10.2–2.10.4, regarding fire emergencies involving radioactive substances).

16.2.3 It is essential that notices are posted in or near every controlled or supervised area where radioactive substances are used showing:

(a) the system of warning people in the vicinity,

(b) the system for contacting the radiation protection supervisor, to whom the emergency is to be notified immediately,

(c) arrangements for calling the fire brigade and medical services, and

(d) the location and method of use of emergency equipment including fire-fighting equipment.

16.2.4 An up-to-date list should be included in the local rules and/or the notices showing the names and telephone numbers of people to be notified according to the circumstances.

16.2.5 Equipment should be kept available for use in an emergency where unsealed radioactive materials are used with activities in excess of those specified in 16.1.2 for Class 1, 2 and 3 nuclides, and in excess of 3 GBq (80 mCi) for Class 4 nuclides. The essential items depend on the type of work being carried out, but consideration should be given to the inclusion of the following:

(a) overshoes, protective clothing, including gloves and caps, and respirators or breathing apparatus (see 16.2.6),

(b) decontamination materials for the affected area, including absorbent material for wiping up spills,

(c) decontamination materials for persons,

(d) barriers, or means for roping off affected areas,

(e) appropriate warning notices,

(f) handling tools and receptacles for contaminated articles,

(g) portable monitoring equipment, including personal monitoring devices, such as pocket dosemeters, thermoluminescent dosemeters and film badges (drawn from current stocks as necessary),

(h) non-porous floor covering, such as Kraft paper, to be used only after any liquid spill has been cleared up,

(i) sundry items, such as adhesive tape, labels, torch, notebook and pencils, and simple first-aid equipment.

Emergency equipment should be kept, as far as practicable, in a clearly labelled suitcase or similar container in readily accessible site. Fire-fighting equipment is referred to in 2.10.2.

16.2.6 Respiratory protective equipment must be of a type which has been certified by a test house holding a HSE certificate of approval (Reg 23(1)). The equipment, and all readily detachable parts, should carry an identifying mark and should be thoroughly examined by a radiation protection supervisor every six months while awaiting issue. His signed and dated report, containing full details of the examination, should be available for inspection. The equipment should be kept clean (see 16.4.7).

16.2.7 Where appropriate, contingency arrangements must be rehearsed at suitable intervals (Reg 31 and ACl/226). Rehearsals should be held wherever conditions are such that a serious emergency might occur, for example dispersal of radioactive material in excess of the activities shown in Table 2.1 or inability to retract a radioactive source or close a shutter resulting in the exposure of persons to high dose rates. The exercises should be designed to test the effectiveness of the arrangements and to ensure that all persons concerned know what action to take. Mock or low activity sources should be used during training exercises, so far as practicable.

16.3 Action during an emergency

16.3.1 The best course of action in an emergency depends very much on local circumstances and the nature of the emergency. If it involves an X-ray set or accelerator, whose exposure controls have failed, it is necessary only to switch off the main supply in order to remove all radiation hazards, except possibly from induced radioactivity in the case of high energy accelerators. If radioactive material is present the emergency may involve:

(a) a high dose rate (see 16.3.10), or

(b) actual or potential dispersal of activity (see 16.3.2–9).

Occasionally both hazards may be present.

16.3.2 In some circumstances the most urgent need would be to summon the fire services or medical assistance; otherwise the normal priorities where radioactive materials have been dispersed would be:

(a) to warn people in the immediate vicinity of the accident,

(b) to notify the radiation protection supervisor who could issue further warnings and summon further aid as required,

(c) to render first aid to anyone who may be seriously injured,

(d) to deal with the emergency or evacuate the area as dictated by circumstances.

16.3.3 Until an appropriate plan has been worked out by the radiation protection supervisor only the minimum immediate action should be taken.

16.3.4 Except where the person in charge decides that it is necessary immediately to evacuate the area (see 16.3.5), attempts should normally be made in the case of solids and liquids to limit the dispersal of the radioactive substance or in the case of radioactive gases or vapour to disperse them as quickly as possible.

16.3.5 In the case of serious spills or source breakage, for example those believed to involve more than ten times the activities specified in 16.1.1, immediate consideration should be given by the person in charge to the prompt evacuation of the laboratory or area.

16.3.6 If evacuation is required, and where time permits, all functioning apparatus in the area should be made safe. Laboratory services except lighting, but including ventilation, should be switched off and all doors and windows should be closed. However, when radioactive gas or vapour, such as tritiated water vapour, is to be dispersed, mechanical ventilation should be left on and, with discretion, doors and windows should be opened.

16.3.7 As far as practicable, attempts should be made to prevent contamination, particularly on shoes or clothing of persons leaving the affected area, from being carried to other areas. Contaminated persons should not move far until they have been monitored and, if necessary, decontaminated. However, the treatment of serious injuries will clearly have to take precedence over decontamination and containment of contamination.

16.3.8 Provided that the wearer is not injured, all clothing contaminated in an emergency should be removed immediately and left in or near the affected area. Contaminated parts of the body should be washed thoroughly until either monitoring shows that contamination will not be significantly reduced by this method, or there is danger of roughening or breaking of the skin which would allow contamination to enter the bloodstream. If contamination still exceeds the relevant value shown in Appendix 4, the advice of the appointed doctor should be sought. In the meantime, any contaminated wound, however trivial, should be irrigated with water or saline solution, care being taken to limit any spread of contamination to other parts of the skin.

16.3.9 People entering the affected area to carry out emergency procedures should wear protective clothing and equipment.

16.3.10 A direct radiation hazard may arise through loss of shielding or through failure of a shutter or source transport mechanism. Unless the source can be rapidly transferred to a protected receptacle using a long-handled tool, the immediate area should be evacuated and barriers erected. Temporary shielding should be applied where this is practicable.

16.3.11 In the case of a serious emergency, the radiation protection adviser should be informed immediately.

16.3.12 If a source is lost, or thought to be lost:

(a) The person responsible for security of sources see 14.2, as well as the radiation protection supervisor, should be informed without delay. The radiation protection supervisor should arrange for an immediate search for the lost source to be made by a competent person. The possibility that the lost source might have fallen into a gap in protective material should not be overlooked.

(b) The radiation protection adviser should also be informed.

(c) All means by which the lost source might be moved further astray should, as far as possible, be eliminated, until the search referred to under (a) has been carried out. For example, there should be no sweeping of floors and no disturbing of furniture, sinks, and so on. Any incinerators which might be involved should not be further used and the ashes should not be disturbed.

(d) Should there be any reason to suspect that the lost source might have become damaged, the possibility of contamination by spilled radioactive substances should be borne in mind. On the earliest indication of such contamination, rigorous precautionary measures should be instituted at once.

Similar action is required if a quantity of unsealed radioactive material is lost.

16.3.13 If necessary, assistance should be summoned from outside the establishment, for example from the National Radiological Protection Board.*

16.4 Action when the immediate emergency is over

16.4.1 Appropriate action should be taken by properly trained and equipped persons to ensure that closed sources are fully shielded, to recover and remove material from broken sources and containers, using handling tools, and to clear up the contamination of the working area according to the circumstances. Some methods of decontamination are given in 12.8.

16.4.2 It is essential that access to the affected area is restricted until all the appropriate action has been taken to clear the contamination from the area and radiation surveys have satisfied the radiation protection supervisor that the area may be re-occupied. Any apparatus should be examined for defects before it is re-energised and working positions should be monitored.

16.4.3 Notification of HSE,*† the appropriate government departments and the police may be required in accordance with 2.2.6 — 2.2.9. This should be carried out without delay, for example, if a lost source is not speedily found.

16.4.4 Personal dosemeters worn by persons involved in the emergency should be sent immediately to the approved laboratory for dose assessment unless the emergency was one which would not have resulted in a detectable external dose. The need for tests to determine the activity which has entered the body, and hence the committed dose, should be considered for all persons who may have ingested or inhaled radioactive substances whether or not they are subject to routine internal monitoring (See 4.2). It is essential that the controlling authority arranges for any special examinations of the affected persons which the appointed doctor requires or recommends (see 3.7).

16.4.5 It is essential that the radiation protection adviser carries out an investigation of the emergency and makes a report to the controlling authority with recommendations fo avoiding its recurrence. An incident must be reported and investigated if it is believed to have caused any worker or member of the public to receive an over-exposure (Reg 9) (See 2.3.1).

16.4.6 If it is suspected that a source or article subject to leak testing may have been damaged in the incident, a leak test should be carried out as soon as possible by an authorised person (AC1/206).

16.4.7 Respiratory protective equipment should be thoroughly cleaned and disinfected after use according to the maker's instructions (AC1/176). When necessary it should be decontaminated.

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*In Northern Ireland, the Northern Ireland Radiation Protection Service.

†In Northern Ireland, the Department of Manpower Services.

Appendix 1
Dose equivalent and related quantities

Dose equivalent

1. The absorbed dose, D, is insufficient by itself to predict either the severity or the probability of deleterious health effects. In radiation protection it has been found convenient to introduce for this purpose a quantity called dose equivalent. This quantity is the absorbed dose weighted by the modifying factors Q and N, discussed below. The dose equivalent, H, at a point in tissue is given by the equation:

$$H = DQN$$

2 At the present time the ICRP has assigned a value of 1 to N, which might otherwise take into account factors such as dose rate and fractionation. The quality factor, Q, allows for the varying efficiencies of different types of radiation for producing biological effects and is defined as a function of the linear collision stopping power (L_{∞}) in water of an ionising particle at the point of interest. Values of Q as a function of L_{∞} are recommended by ICRP and are given in ICRP Publication 26.[58]

3 For a spectrum of directly or indirectly ionising radiation an effective value, $\overline{Q}$, of Q at the point of interest can be calculated. When the distribution of L_{∞} for the radiation is not known or cannot easily be calculated it is permissible to use approximate values of $\overline{Q}$ related to the type of primary radiation. For this purpose the ICRP recommends the following values of $\overline{Q}$ for both internal and external radiation:

X-rays, γ-rays and electrons	1
Neutrons, protons and singly-charged particles of rest mass greater than one atomic mass unit of unknown energy	10
α particles and multiply-charged particles (and particles of unknown charge), of unknown energy	20

Deep dose equivalent index

4 The deep dose equivalent index $H_{I,d}$, is the maximum value of the dose equivalent at a depth of 1 cm or more in a tissue sphere of 30 cm diameter. This quantity is often easier to assess for practical situations of external exposure than the effective dose (see 1.2.3).

Shallow dose equivalent index

5 The shallow dose equivalent index, $H_{I,s}$, is the maximum value of dose equivalent in a shell from 0.07 mm to 10 mm in depth in a tissue sphere of 30 cm diameter. This quantity may be used as an assessment of the dose to the skin from external radiation.

Deep dose equivalent

6 This quanity is defined in the approved code as the dose equivalent at a depth of a 1 g cm^{-2} in material corresponding to soft tissue (AC1/46(b)).

Shallow dose equivalent

7 This quantity is defined in the approved code as the dose equivalent averaged between depths of 5 and 10 mg cm^{-2} in material corresponding to soft tissue (AC1/46(b)).

Committed dose equivalent

8 When a quantity of a radioactive substance is deposited in a body organ or tissue by single intake, the dose equivalent to that organ or tissue resulting from that intake which is accumulated over the following 50 years, representing a working life, is known as the committed dose equivalent, H_{50}. This may be represented by the equation:

$$H_{50} = \int_{t_0}^{t_0 + 50a} \dot{H}(t)\, dt$$

where $\dot{H}(t)$ is the dose equivalent rate in the organ or tissue and t_0 is the time of intake.

Committed effective dose equivalent

9 The committed effective dose equivalent to the whole body is the weighted sum of the committed dose equivalents to individual organs or tissues, when the weighting factors are those shown in Table 1.2.

Annual limit on intake (ALI)

10 This is a secondary limit designed to meet the basic limits for occupational exposure where due to internal sources. It is defined as the activity of a radionuclide which, taken alone, would irradiate a person, represented by Reference Man, (57) to the limit set for each year of occupational exposure. Therefore, when intake is less than the ALI, neither the committed effective dose equivalent to the whole body nor the committed dose equivalent to any individual organ or tissue would, in any year, exceed the respective annual dose limits. ALIs for intake by inhalation or ingestion have been calculated by ICRP Committee 2 and are shown in ICRP Publication 30(61). No other limitation of rate of intake is recommended by ICRP except in the case of occupational exposure of women of reproductive capacity and pregnant women. However, the principle of 'as low as reasonably achievable' applies also to intake.

11 For a mixture of radionuclides the ALI may be taken as follows:

(a) if the composition is known, the intake such that:

$$\Sigma \frac{I_j}{I_{j,L}} = 1$$

where I_j is the intake during the year of the radionuclide j

and $I_{j,L}$ is the ALI for that radionuclide;

(b) if the concentration of one of the radionuclides is such that its toxicity predominates, the ALI for that radionuclide;

(c) if the exact composition is not known but the radionuclides present have been identified, the lowest ALI for any radionuclide known to be present;

(d) if the composition is not known but the presence of certain radionuclides can be positively excluded, the lowest ALI for any radionuclide that may be present. (AC1/46(a)).

Appendix 2
Administrative organisation for radiological safety

The example below indicates the type of administration organisation suitable in a large establishment. The safety committee is assumed to have been set up under the Safety Representatives and Safety Committees Regulations 1977 (9) (and the equivalent Northern Ireland Regulations).

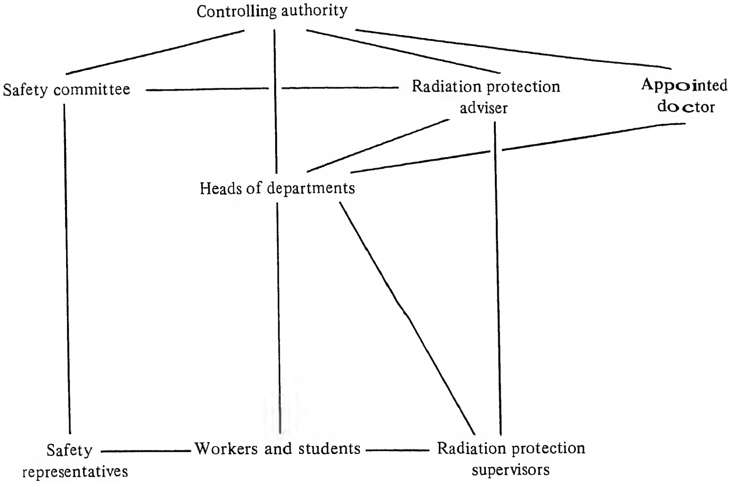

Fig 1 Organisational structure in a large establishment.

Appendix 3

Signs to indicate ionising radiation

1 British Standard 3510: 1968 (92) specifies a basic symbol (see Fig. 2) to denote the actual or potential presence of ionising radiation and to identify objects, devices, materials or substances which emit ionising radiation. The Standard does not specify any radiation levels at which the symbol is to be used.

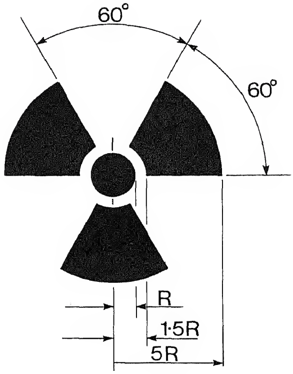

Fig 2 Basic ionising radiation symbol.

2 The areas shown shaded in Fig 2 are black. The background should be yellow, of a colour approximating to colour No. 309 of British Standard 381C. However, the symbol on a white background is required for labels on some packages containing radioactive materials and for placards on certain vehicles transporting radioactive materials (see Appendix 5).

3 British Standard 5378: Part 1: 1980 (103) specifies various types of safety sign including a warning sign indicating 'Caution, risk of ionising radiation'. This sign (see Fig 3) is triangular in shape, has a yellow background and a black border, and the radiation symbol is placed centrally on the background. It is specified that at least 50% of the area of the safety sign shall be yellow; consequently, the relative sizes of the triangle and of the symbol have to satisfy the following conditions:

$$\ell \geqslant 27R$$

It is essential that the warning sign and radiation symbol are sufficiently large to be distinctive and that the sign is fixed in a prominent position.

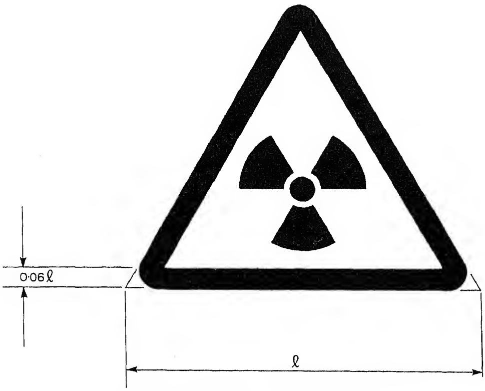

Fig 3 Warning sign — ionising radiation.

4 Explanatory wording may be needed. This should be put on a supplementary sign. BS 5378 specifies that supplementary signs shall be oblong or square with the text in black on a background which is either white or of the same colour as the safety sign (that is, yellow in the case of a warning sign). The wording might be used to identify a controlled or supervised area, to give information about access, to indicate the nature of the source of radiation or the type of radiation, to draw attention to special precautions, and so on. The number of words should be kept to the minimum necessary.

5 A warning sign and its supplementary sign may, if desired, be mounted on a common, white background. Examples of warning and supplementary signs are given in Figs 4, 5 and 6.

6 The preferred sizes for the overall height of safety signs are given in Appendix A to BS 5378: Part 2: 1980,(103) namely 10cm, 15cm, 30cm, 50cm, 120cm. Guidance on the size of wording for specific signs may be found in BS 5499: Part 1.

7 All safety signs giving health or safety information or instruction to persons at work (apart from the exceptions referred to in paras 8 and 9 below) which are put up after 1 January 1981 must comply with BS 5378: Part 1 (the Safety Signs Regulations 1980).(43) Existing signs do not need to be changed immediately but all safety signs must comply with the British Standard by 1 January 1986. These requirements apply in particular to radiation warning signs. They apply not only when display of a sign is required by particular regulations or an approved code of practice but also when a sign is displayed voluntarily. A warning sign may have been attached to a piece of equipment by its manufacturer but it is the controlling authority's responsibility to see that the Safety Signs Regulations are complied with. Signs specified in the British Standard may be displayed only to provide the health or safety information or instruction indicated by that sign. They must therefore be taken down when not required.

8 Labels or marking on a package or container are excluded from the Safety Signs Regulations. This allows the use of the labels specified in the Radioactive Substances (Carriage by Road) (Great Britain) Regulations 1974 (40) (and in other documents). These labels include the radiation symbol but not the radiation warning sign. This exclusion is not restricted to transport and it is acceptable to label a bottle in a laboratory as Fig 7. However, the door of a cupboard in which the bottle is kept shold be labelled with the triangular radiation warning sign.

9 Apart from the radiation warning sign, other safety signs may be needed for protection against ionising radiation, for example, a sign requiring gloves to be worn in a laboratory handling radioactive material or a sign to indicate the location of emergency equipment. These signs also must conform with BS 5378: Part 1, except where they relate to fire fighting or rescue equipment or emergency exits; BS 5499: Part 1, BS 2560 and BS 4218 should then be referred to.

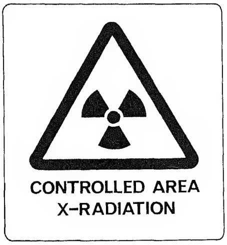

Fig 4 Sign at the boundary of a controlled area.

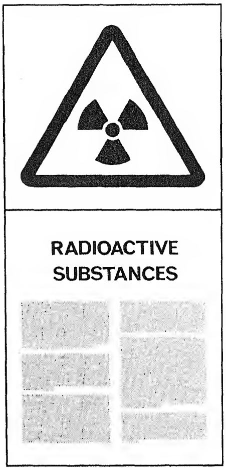

Fig 5 Sign on a storage cabinet for radioactive materials.

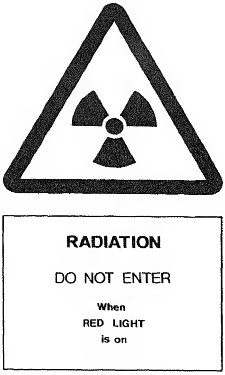

Fig 6 Sign at the entrance of a radiography enclosure.

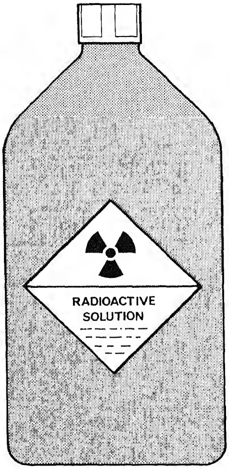

Fig 7 Label on a bottle containing radioactive solution.

Appendix 4
Derived limits for surface contamination

1 The derived limits for surface contamination, whether removable or fixed, are given in Table A 4.1. Surfaces should be cleaned whenever they become contaminated; decontamination is essential if these levels are exceeded.

2 For the purpose of controlling surface contamination, radionuclides are divided into five classes, as shown in Table A 4.2. These classes are quite distinct from the radiotoxicity groups.

3 It is essential that the contamination of surfaces of the body and of clothing is assessed by direct measurement. For other surfaces, direct monitoring should be employed wherever practicable. If wipe testing is employed, it should be assumed that ten per cent of the contamination has been transferred to the swab unless other information is available.

4 Measurements of the contamination of surfaces of the body may be averaged over an area not exceeding 100 cm^2 (paragraph 3 of Schedule 1 of the regulations). For floors, walls and ceilings, the measurements may be averaged over an area not exceeding 1000 cm^2; for other surfaces, over an area not exceeding 300 cm^2. If there is reason to believe that discrete specks of a beta emitter may be embedded in clothing, the latter should be monitored with an averaging area of 1 cm^2.

5 The limits given in Table A 4.1 do not apply to volatile compounds and to radionuclides in forms that can readily penetrate the skin.

6 The approximate equivalents in special units of the values given in Table A 4.1 are as follows:

3×10^{-1} Bq cm^{-2}	10^{-5} μCi cm^{-2}
3	10^{-4}
3×10	10^{-3}
3×10^2	10^{-2}
3×10^3	10^{-1}

7 Guidance on monitoring and on decontamination, including the action to be taken when contamination is not easily removable, is given in 4.3, 12.7 and 12.8.

Table A 4.1

Category	*Surface*	*Derived limit (Bq cm^{-2})*					
		Class I	Class II	Class III		Class IV	Class V
				emitters	others		
A	Surfaces of the interiors and contents of glove boxes and fume cupboards	The minimum reasonably achievable					
	Surfaces of controlled areas and of plant, apparatus, equipment (including personal protective clothing), materials and articles within controlled areas other than those in Category A	*† 3×10^{-1}	*3	3×10^1		3×10^2	3×10^3
C	Surfaces of the body	†‡ 3×10^{-1}	3×10^{-1}	3×10^{-1}	3	3×10^1	3×10^2
D	Supervised and public areas, personal clothing	† 3×10^{-1}	3×10^{-1}	3		3×10^1	3×10^2

*May be increased by a factor of 10 if the extent of contamination is less than 1 m^2.
†For ^{231}Pa use a tenth of this value.
‡For ^{237}Np use a tenth of this value.

Table A 4.2

Class	*Radionuclide*
I	^{227}Ac, ^{228}Th, ^{230}Th, ^{232}Th, Th-nat, ^{231}Pa, ^{232}U, ^{233}U, ^{234}U, ^{236}U, alpha emitters with $Z>92$
II	^{147}Sm, ^{210}Pb, ^{227}Th, ^{235}U, ^{238}U, U-depl, U-nat, U-enr, ^{241}Pu
III	All nuclides which are not in the other classes
IV	^{14}C, ^{35}S, ^{54}Mn, ^{57}Co, ^{65}Zn, ^{67}Ga, ^{75}Se, ^{77}Br, ^{85}Sr, ^{99}mTc, ^{109}Cd, ^{123}I, ^{125}I, ^{129}Cs, ^{197}Hg, ^{201}Tl
V	^{3}H, ^{51}Cr, ^{55}Fe, ^{63}Ni, ^{131}Cs

Appendix 5

Transport of radioactive materials outside research establishments, universities and colleges

1 An outline is given in this appendix of the regulations,* codes of practice* or conditions* which apply to various modes of transport in relation to radioactive materials† used in research and teaching. It is emphasised that this information is presented only as a guide and that the original documents should be consulted for a complete and authoritative statement of the requirements. The transport of fissile materials is not considered in this Appendix.

2 There are regulations governing the transport of radioactive materials in the United Kingdom by road (40,41), sea (42) and air(43) ; these are supplemented by codes of practice. (114-116) The British Railways Board and the Post Office issue their own conditions of acceptance. (117,118) (Only materials and articles of low activity may be sent by post.)

For transport outside the United Kingdom, there are regulations and codes covering carriage by air,(84) sea,(85) road,(86) rail (87) and post. (118)

All these documents are based on the International Atomic Energy Agency (IAEA) Transport Regulations. (66,72)

3 One of the following types of package will usually be required:

(a) Exempt package,

(b) Type A capable of withstanding normal transport conditions and minor accidents, such as being soaked in heavy rain, dropped from the tailboard of a lorry or struck by a sharp object,

(c) Type B (U) designed to withstand severe accident conditions including fire.

'Exempt' packages are exempt from the majority of transport requirements but are subject to quantity limitations and to certain conditions (see paragraph 9 of this appendix). Design features of Types A and B (U) packages and the assessment of packaging are dealt with in detail in the IAEA Transport Regulations and British Standard 3895.(94) Type B (U) packaging needs prior approval by the competent authority which, for the United Kingdom, is the Secretary of State for Transport.

4 Types A and B (U) packages must be:

(a) Not less than 10 cm for the smallest external dimension,

(b) Leakproof‡ with respect to contents,

(c) Sealed as evidence that it has not been opened without authority, and any fastening device securely closed,

(d) Shielded to the required extent (see para. 7),

(e) Sufficiently free of external contamination (see para. 11).

5 The maximum activity permitted in a type A package is normally the value A_2 for the radionuclide involved. However, if the material is in Special Form a maximum activity, A_1, is permitted. Values of A_1 and A_2 for some commonly used radionuclides are shown in Table A 5.1.

Material in Special Form must have at least one dimension not less than 5 mm and comply with the relevant IAEA test requirements. One type of Special Form is a sealed capsule containing radioactive material and so constructed that it can be opened only by destroying the capsule. Many sealed sources are in Special Form but this description may be used only if the design has been approved by the Secretary of State or by the competent authority of the country of origin of the design.

6 The maximum activity that may be transported in a type B (U) package is that specified in the competent authority's approval certificate for that package.

7 The external dose rate from packages is subject to limitations which enable three categories of packages to be defined, regardless of whether they are of type A or type B (U):

Category I	WHITE	Packages where the surface dose rate does not exceed 5 μSv h^{-1} (0.5 mrem h^{-1}).
Category II	YELLOW	Packages where the surface dose rate exceeds 5 μSv h^{-1} (0.5 mrem h^{-1}) but does not exceed 0.5 mSv h^{-1} (50 mrem h^{-1}) and

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*In this appendix the word 'must' is used to describe the requirements of any of these documents.

†Defined, for transport, as having a specific activity exceeding 0.002 μCi (74 Bq) per gram of material in which the radionuclides are essentially uniformly distributed.

‡After prescribed tests, a small loss of contents is permitted from type B (U) but not from type A.

the dose rate at 1 metre from the external surface does not exceed 10 μSv h^{-1} (1 mrem h^{-1}).

Category III YELLOW — Packages where the Category II limits are exceeded but the surface dose rate does not exceed 2 mSv h^{-1} (200 mrem h^{-1}) and the dose rate at 1 metre from the external surface does not exceed 0.1 mSv h^{-1} (10 mrem h^{-1}). (Under 'full load conditions', that is to say when the consignor has sole use of the vehicle, the maximum dose rate is higher).

Completed white or yellow labels, of the prescribed type, must be affixed to two opposite sides of a type A or type B (U) package before transport. The Transport Index to be shown on a Yellow label package is the dose rate in mrem h^{-1} at 1 m from the external surface.

8 In regard to Category II and III Yellow packages only, the total number which may be transported or stored together is limited by the Transport Index. Tables showing the distances by which radioactive packages are to be segregated from persons and undeveloped film are given in the appropriate regulations or codes of practice in terms of the sum of the transport indexes. In general, the sum of the transport indexes in a vehicle is limited to 50.

9 Small quantities of radioactive materials and instruments and manufactured articles, such as clocks, electronic tubes or apparatus having radioactive material as a component part, may be sent in exempt packages if securely packed so that there can be no leakage of radioactive material under normal conditions of transport and if the activities do not exceed those shown in Table A 6.2. The marking 'Radioactive' is required on each instrument or article, except for those which are radioluminescent, and on the inner packaging of radioactive material so that a warning of the presence of radioactive material is visible on opening the package. Articles made from depleted uranium (but not otherwise radioactive) may be sent in exempt packages if the outer surface of the uranium is covered with a substantial, inactive sheath. The dose rate at the surface of an exempt package must not exceed 5 μSv h^{-1} (0.5 mrem h^{-1}) and that at 10 cm from the surface of an unpackaged instrument or article must not exceed 0.1 mSv h^{-1} (10 mrem h^{-1}).

10 Empty packages which have contained radioactive materials are exempt if they have been decontaminated internally and no White or Yellow labels are visible.

11 The removable radioactive contamination of the external surfaces of packages, including exempt packages, is limited to not more than 10^{-5} μCi cm^{-2} (0.3 Bq cm^{-2}) for alpha emitters and 10^{-4} μCi cm^{-2} (3 Bq cm^{-2}) for beta or gamma emitters. These values apply to averages obtained over an area of 300 cm^{2}.

12 When White or Yellow label packages are transported there will usually need to be a consignor's certificate, containing prescribed particulars of the consignment. This has to be given to the carrier or, if the consignor is carrying the goods, to the driver. Any relevant approval certificate must also be given to the carrier if he is not the consignor. The vehicle must bear placards at the sides and rear.

13 Packages containing radioactive materials may be conveyed by passenger or freight train but only in accordance with the relevant regulations. They are prohibited on the London Underground system and in public service vehicles such as buses and coaches.

14 For road transport, a fire proof notice must be exhibited in the driver's cab, measures must be taken to limit the dose rate to the driver and there are restrictions on passengers. There are also requirements regarding security and, if Yellow label packages are being carried, on parking in public places. The driver will need to be given instructions on action to be taken in the event of an accident such as a road accident or a lost or damaged package. This will include informing the police who can, if necessary, obtain radiological advice or assistance under National Arrangements for Incidents involving Radioactivity (NAIR).

15 The transport of radioactive substances by post is, in general, prohibited. However, suitably packed materials, instruments and articles, having an activity not exceeding one-tenth of the package limits shown in Table A 6.2, are admitted if the surface dose rate does not exceed 5 μSv h^{-1} 0.5 mrem h^{-1}. Containers and receptacles as well as information about the chemical nature of the radioactive substance must be referred to Postal Headquarters for approval. There are special marking requirements for packages transported by post; these are different for inland post and overseas post. Packages sent by overseas post must be registered.

16 Normal transport requirements do not apply to the carriage of animals made radioactive in the course of experiments or radioactive carcasses. However, the vehicle must be checked periodically for contamination.

17 Advice in respect of all modes of transport, except by post, for the whole of the United Kingdom can be obtained from the Head of the Radioactive Materials Transport Division.

Table A 5.1 Activity limits for Type A packages

Radionuclide	Mass number	A_1	A_2
		CURIES	CURIES
Americium	241	8	0.008
Barium	133	40	10
Bismuth	207	10	10
Caesium	137	30	20
Californium	252	2	0.002
Carbon	14	1000	100
Cobalt	57	90	90
	58	20	20
	60	7	7
Germanium	68	20	10
Iodine	125	1000	70
Iridium	192	20	20
Iron	55	1000	1000
Krypton	85	1000*	1000*
Lead	210	100	0.2
Nickel	63	1000	100
Polonium	210	200	0.2
Promethium	147	1000	80
Radium	226	10	0.05
Ruthenium	106	10	7
Samarium	151	1000	90
Sodium	22	8	8
Thallium	204	300	30
Strontium	90	10	0.4
Tritium	3	1000‡(20§)	1000‡(20§)
Uranium†	238	unlimited	unlimited

*uncompressed

†also natural and depleted uranium

‡gas, activated luminous paint, absorbed on a solid carrier and tritiated water
§other forms
A_1 is for Special Form

A_2 is for other forms

The values of A_1 and A_2 in SI Units are obtained by using the conversion:

1 Ci = 37 GBq
100 Ci = 3.7 TBq

Table A 5.2 Activity limits for exempt materials, instruments and articles

Nature of contents	*Instruments and articles*		*Materials*
	Item limits	Package limits	Package limits
Solids			
Special form	10^{-2} A_1	A_1	10^{-3} A_1
Other forms	10^{-2} A_2	A_2	10^{-3} A_2
Liquids			
Tritiated water			
<0.1 Ci/1	—	—	1000 Ci
between 0.1 CVi/1 and 1.0 Ci/1	—	—	100 Ci
>1.0 Ci/1	—	—	1 Ci
Other liquids	10^{-3} A_2	10^{-1} A_2	10^{-4} A_2
Gases			
Tritium	20 Ci	200 Ci	20 Ci
Special form	10^{-3} A_1	10^{-2} A_1	10^{-3} A_1
Other forms	10^{-3} A_2	10^{-2} A_2	10^{-3} A_2

Appendix 6
Temporary preservation of radioactive animal carcasses until sufficient radioactive decay has taken place for disposal

1 *Carcasses weighing less than approximately 3.5 kilograms*

The carcasses or tissue may be placed in a polythene bag with fresh bleaching powder and dry Vermiculite (a commercial expanded mica). If the polythene bag is then heat-sealed and the carcass tumbled about in the mixture until it is thoroughly dusted, decomposition will be prevented for a considerable time. The following additional action is essential to the success of this process:

(a) the open end of the bag, which should be made of the heavier gauge, 250-500, of polythene, should be folded back in a double cuff fold outwards to protect the surfaces to be sealed from dust and inorganic matter;

(b) the weight of the bleaching powder and dry Vermiculite should each be not less than one-fifth of the weight of the carcass. This represents, in practice, a volume of about 300 ml and 1500 ml respectively per kilogram weight of carcass;

(c) it is desirable to slit the carcass ventrally along the midline, if this has not already been done, before placing it in the bag;

(d) the animal's claws should be cut and feet of the carcass should be bound with adhesive tape, lint or bandage before it is placed in the bag, to avoid the possible penetration of the bag. For the same reason it is unwise to sever the feet with bone forceps lest sharp splinters are left;

(e) if the carcass is soiled with tissue fluid or blood, it should be dusted with bleaching powder and allowed to cool before being placed in the bag. This avoids the development of heat inside the bag due to the rapid interaction of the bleaching powder and organic matter. Heating may also be avoided by applying dry Vermiculite to the opened carcass. The finer grades of this material absorb about four times their own weight of fluid and thus the interaction with the bleaching powder is slowed down; and

(f) the bag should be sealed with only a small amount of air included, but in expelling the air, care should be taken not to blow dust on the surfaces to be sealed. For further information, see Boursnell, J C and Gleeson-White, M H. *Nature,* Lond. 179, 54, 1957.

2 *Carcasses weighing more than approximately 3.5 kilograms*

The method described above is also effective for animal carcasses weighing slightly more than 3.5 kilograms provided they have been carefully eviscerated, but larger carcasses require different treatment, as follows:

(a) the carcass should be eviscerated and the intestines, liver and stomach slit open;

(b) the chest cavity should be cut wide open and the lungs and heart slit; the latter sometimes allows a useful measure of exsanguination; and

(c) the carcass should then be stored in a strong plastic dustbin with a well fitting lid and 40% formalin solution added to cover the carcass completely.

Note: Care in following the above directions will ensure that there is no putrefaction.

(d) it is essential to store the bins at a properly-appointed place away from sunlight and heat and identified by a label showing the nature and approximate quantity of the radioactive material contained;

(e) storage should last until the level of the radioactivity is sufficiently low to permit the fluid to be poured down the drain and the carcass to be incinerated in the normal way; and

(f) owing to selective accumulation of certain isotopes by certain organs it is not always necessary to preserve the complete carcass. The organs concerned should be removed for storage as above but it may be safe to incinerate the remainder of the carcass immediately.

3 Further advice on the disposal of radioactive carcasses can be obtained from the Department of the Environment.*

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*In Scotland, the Scottish Development Department and in Northern Ireland, the Department of the Environment for Northern Ireland.

Appendix 7
Guidance on terms used

Approved laboratory	laboratory, approved by the Health and Safety Executive, which provides a personal dosimetry and dose record keeping service for external and/or internal sources of radiation.
Closed source	radioactive source from which, by sealing, bonding or other means, dispersal of the radioactive material is minimised. The term includes bonded source, homogeneous source, laminated source and sealed source.
Controlled area	an area, subject to special measures for the purpose of radiation protection, to which access is restricted and inside which a person might receive an annual dose or committed dose, other than from natural background or medical exposure, exceeding three-tenths of the relevant dose limit for workers.
Controlling authority	body or person or persons ultimately responsible for the control of the establishment of the work which is the subject of these guidance notes.
Derived limit	limit derived from the basic or secondary limits of dose equivalent, committed dose equivalent or intake by a defined model of the situation and which is intended to prevent the basic limits from being exceeded. Such limits include dose rate in a work place, contamination of air and contamination of surfaces.
Minimum notifiable quantity	the activity of a radioactive substance above which work would have to be notified under Reg 5 if that substance alone were present and no previous notification had been given (see 2.2.1 and Table 2.1).
Occupancy factor	factor by which the workload may be multiplied for calculating protective shielding in order to take account of the degree or type of occupancy of the area to be protected. This factor should not be used when considering the designation of areas.
Orientation factor	factor by which the workload may be multiplied for calculating protective shielding in order to take account of that part of the workload during which the radiation beam is expected to be directed to the area to be protected. (This factor has formerly been known as the 'use factor'.)
Radioactive substance	strictly, any substance consisting of or containing a radionuclide. However, since even ostensibly stable substances contain trace amounts of radionuclides, a limit has been generally agreed below the radioactivity can be ignored for most purposes. This limit is set such that a substance is considered to be radioactive if the activity concentration exceeds 100 Bq (0.0027 μCi) per gram of that substance; in the case of a chain of radionuclides, consisting of a parent and daughters, the only nuclide to be taken into consideration is that having the highest activity of those present. *Note:* This definition is not in the same terms as that used in the Radioactive Substances Act 1960 for the purposes of disposal of radioactive waste.
Sealed source	any radioactive substance sealed in a container (otherwise than solely for the purpose of storage, transport or disposal) or bonded wholly within material, the container or bonding having sufficient strength to prevent any dispersion of the radioactive substance under normal conditions of use. The term 'sealed source' includes the immediate container or the bonding.
Supervised area	an area, not forming part of a controlled area, that is subject to appropriate supervision for the purpose of radiation protection, and inside which a person might receive an annual dose or committed dose, other than from natural background or medical exposure, exceeding one-tenth of the relevant dose limit for workers.
Workload	a measure in suitable units of the amount of use of equipment generating ionising radiation.

Appendix 8

Addresses of organisations mentioned in the guidance notes

Health and Safety Executive 25 Chapel Street London NW1 5DT Tel: 01-262 3277	Ionising Radiations Regulations and Approved Code of Practice (Communications should normally be made through the local area office)
Department of Manpower Services Netherleigh Massey Avenue Belfast BT4 2JP Tel: Belfast (0232) 3244	Manpower in Northern Ireland
Radiochemical Inspectorate Department of the Environment Becket House Lambeth Palace Road London SE1 7ER Tel: 01-211 3000	Storage of radioactive materials and disposal of radioactive waste in England
H M Industrial Pollution Inspectorate for Scotland Scottish Development Department New St Andrew's House St James Centre Edinburgh EH1 3SZ Tel: 031-556 8400	Storage of radioactive materials and disposal of radioactive waste in Scotland
Environment Protection Unit Welsh Office Pearl Assurance House Greyfriars Road Cardiff CF1 3RT Tel: Cardiff (0222) 44151	Storage of radioactive materials and disposal of radioactive waste in Wales
Alkali and Radiochemical Inspectorate for Northern Ireland Department of the Environment for Northern Ireland Stormont Belfast BT4 3SS Tel: Belfast (0232) 63210	Storage of radioactive materials and disposal of radioactive waste in Northern Ireland
Home Office General Department, E4 Division 50 Queen Anne's Gate London SW1H 9AT Tel: 01-213 3000	Animal experiments
Department of Education and Science Elizabeth House York Road London SE1 7PH Tel: 01-928 9222	Use of radiation sources at establishments of further education and colleges of education
Scottish Education Department New St Andrew's House St James Centre Edinburgh EH1 3SY Tel: 031-556 8400	Use of radiation sources at establishments of further education and colleges of education in Scotland
Welsh Office Education Department Crown Buildings Cathays Park Cardiff CF1 3NQ Tel: Cardiff (0222) 825111	Use of radiation sources at establishments of further education and colleges of education in Wales

Department of Education for Northern Ireland Rathgael House Balloo Road Bangor County Down BT19 2PR Tel: Bangor (0247) 66311	Use of radiation sources at establishments of further education and colleges of education in Northern Ireland
Department of Transport Radioactive Materials Transport Division 2 Marsham Street London SW1P 3EB Tel: 01-212 3434	Transport of radioactive materials in Great Britain
Department of the Environment for Northern Ireland Stormont Belfast BT4 3SS Tel: Belfast (0232) 63210	Transport of radioactive materials in Northern Ireland
The Post Office Postal Headquarters (PMk1) St Martin's-le-Grand London EC1A 1HQ Tel: 01-432 1234	Transport of radioactive materials by post
National Radiological Protection Board Chilton Didcot Oxfordshire OX11 0RQ Tel: Abingdon (0235) 831600	General advice and services in the South of England and in Wales
National Radiological Protection Board Hospital Lane Cookridge Leeds LS16 6RW Tel: Leeds (0532) 679041	General advice and services in the North of England
National Radiological Protection Board 155 Hardgate Road Glasgow G51 4LS Tel: 041-440 2201	General advice and services in Scotland
Northern Ireland Radiation Protection Service Belvoir Park Hospital Saintfield Road Belfast BT8 8JR Tel: Belfast (0232) 642942	General advice and services in Northern Ireland

Appendix 9
References and bibliography

Acts and regulations

1 Radioactive Substances Act 1948 HMSO London.

2 Radioactive Substances Act 1960 HMSO London.

3 Nuclear Installations Act 1965 HMSO London.

4 Nuclear Installations (Amendment) Act 1965 HMSO London.

5 Nuclear Installations Act 1969 HMSO London.

6 Cruelty to Animals Act 1876 HMSO London.

7 Health and Safety at Work etc. Act 1974 HMSO London.

8 The Health and Safety at Work (Northern Ireland) Order 1978 (S.I. 1978 N. 1039 N19) HMSO Belfast.

9 The Safety Representatives and Safety Committees Regulations 1977 (S.I. 1977 No. 500) HMSO London.

10 The Ionising Radiations Regulations 198-.

11 (Corresponding Regulations which are expected for Northern Ireland.)

12 The Radioactive Substances (Luminous Articles) Exemption Order 1962 (S.I. 1962 No. 2644) HMSO London.

13 The Radioactive Substances (Luminous Articles) Exemption (Scotland) Order 1962 (S.I. 1962 No. 2761 S.121) HMSO Edinburgh.

14 The Radioactive Substances (Luminous Articles) Exemption Order (Northern Ireland) 1962 (S.R. & O (N.I.) 1962 No. 251), HMSO Belfast.

15 The Radioactive Substances (Uranium and Thorium) Exemption Order 1962 (S.I. No. 2710) HMSO London.

16 The Radioactive Substances (Uranium and Thorium) Exemption (Scotland) Order 1962 (S.I. 1962 No. 2766 S.126) HMSO Edinburgh.

17 The Radioactive Substances (Uranium and Thorium) Exemption Order (Northern Ireland) 1962 (S.R. & O (N.I) 1962 No. 244) HMSO Belfast.

18 The Radioactive Substances (Prepared Uranium and Thorium Compounds) Exemption Order 1962 (S.I. 1962 No. 2711) HMSO London.

19 The Radioactive Substances (Prepared Uranium and Thorium Compounds) Exemption (Scotland) Order 1962 (S.I. 1962 No. 2772 S.132) HMSO Edinburgh.

20 The Radioactive Substances (Prepared Uranium and Thorium Compounds) Exemption Order (Northern Ireland) 1962 (S.R. & O (N.I.) 1962 No. 242), HMSO Belfast.

21 The Radioactive Substances (Geological Specimens) Exemption Order 1962 (S.I. 1962 No. 2712) HMSO London.

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24 The Radioactive Substances (Waste Closed Sources) Exemption Order 1963 (S.I. 1963 No. 1831) HMSO London.

25 The Radioactive Substances (Waste Closed Sources) Exemption (Scotland) Order 1963 (S.I. 1963 No. 1877 S.94) HMSO Edinburgh.

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27 The Radioactive Substances (Schools etc). Exemption Order 1963 (S.I 1963 No. 1832) HMSO London.

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29 The Radioactive Substances (Schools etc). Exemption Order (Northern Ireland) 1963 (S.R. & O (N.I.) 1963 No. 219) HMSO Belfast.

30 The Radioactive Substances (Electronic Valves) Exemption Order 1967 (S.I. 1967 No. 1797) HMSO London.

31 The Radioactive Substances (Electronic Valves) Exemption (Scotland) Order 1967 (S.I. 1967 No. 1803 S.166) HMSO Edinburgh.

32 The Radioactive Substances (Electronic Valves) Exemption Order (Northern Ireland) 1967 (S.R. & O (N.I.) 1967 No. 313) HMSO Belfast.

33 The Radioactive Substances (Smoke Detectors) Exemption Order 1980 (S.I. 1980 No. 953) HMSO London.

34 The Radioactive Substances (Smoke Detectors) Exemption (Scotland) Order 1980 (S.I. 1980 No. 1599 S.126) HMSO Edinburgh.

35 The Radioactive Substances (Smoke Detectors) Exemption Order (Northern Ireland) 1980 (S.R. (N.I.) 1980, No. 304) HMSO Belfast.

36 The Food (Control of Irradiation) Regulations 1967 (S.I. 1967 No. 385) HMSO London.

37 The Food (Control of Irradiation) (Scotland) Regulations 1967 (S.I. 1967 No. 388 S.29) HMSO Edinburgh.

38 The Food (Control of Irradiation) (Amendment) Regulations 1972 (S.I. 1972 No. 205) HMSO London.

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40 The Radioactive Substances (Carriage by Road) (Great Britain) Regulations 1974 (S.I. 1974 No. 1735) HMSO London.

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42 The Merchant Shipping (Dangerous Goods) Rules 1978 (S.I. 1978 No. 1543) HMSO London.

43 The Air Navigation Order 1976 (S.I. 1976 No. 1783) HMSO London.

44 The Units of Measurement Regulations 1980 (S.I. 1980 No. 1070) HMSO London.

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